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SECTION OF GEOLOGY AND MINERALOGY

THE ELECTRON MICROSCOPE APPLIED TO GEOLOGICAL RESEARCH

By THOMAS F. BATES*

Introduction. The history of microscopy, as applied to the geological sciences, begins in the 1820's with William Nicol, who devised the polarizing device that bears his name[1] and who also described a method of making thin plates of fossil plants.[2] The investigation of thin sections under plain and polarized light was, however, largely a curiosity until the work of H. C. Sorby. In 1859, this scientist, speaking before the Geological Society of France, said:[3] "The study of thin plates of rocks constitutes an entirely distinct branch of geology and demands additional knowledge. In the ten years since I began this, I have prepared many hundreds of these plates, and nevertheless much remains to be done. If I wished to describe all the results to which their examination led, I should have to go into each branch of geology; . . ." Even such a far-sighted scientist as Sorby, however, did not conceive of the tremendous changes in geological thought which were to be produced by this tool in the hands of men such as Zirkel, Rosenbusch, Fouqué, and many others.

Ten years have elapsed since the electron microscope was first applied to geological problems. During this decade, little progress along geological lines has been made compared to that in such fields as bacteriology and metallurgy. Nevertheless, this tool is certain to play an important part in future geological research, and though it may not influence geological thought as greatly as did the petrographic microscope, it will provide the key to the solution of many geological problems.

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Advantages and Limitations of the Electron Microscope. In order fully to appreciate the significance of the electron microscope in geological research, it is important to be aware of the advantages and limitations of the instrument. The most important advantage is the increase of resolution which results when an electron rather than a light beam is used. Whereas the light microscope can only distinguish points as individuals when they are 2,000 angstrom units (0.2 microns) apart, the electron microscope effectively separates in the image two points which are only 10 angstrom units distant in the object.

On the other side of the ledger, the most important limitation in the use of the electron microscope in geology is the low penetrating power of the electron beam. PLATE 1 (A) shows a film of collodion which has broken and doubled over upon itself. Although the film is 1,000 times thinner than a standard thin section, three thicknesses are almost opaque. If this material had a greater density—as for example, that of a sheet of mica—it would have to be still thinner to be translucent.

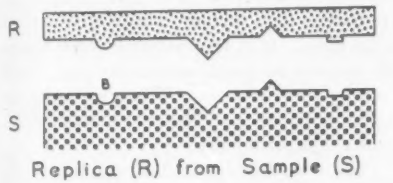
PLATE 1 (B) of diatomaceous earth shows the varying degree of translucence in different portions of the fossil organism. It is apparent that transmission studies with the electron microscope of so-called "thin sections" of rocks and minerals is not practical at the present time. Only in the case of platy or fibrous particles is it likely that the electron beam will penetrate the material.

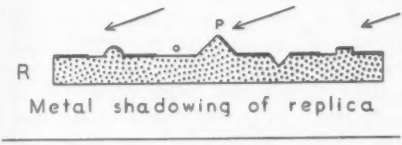
A second limitation arises from the fact that the electron beam operates only in a high vacuum and generates heat in a particle in its path. This is particularly serious in bacteriological work but also affects certain applications to geology.

Finally, it is important to realize that color, birefringence, refractive index, and other optical characteristics which make the petrographic microscope such a valuable

tool, have no significance when dealing with electron optics.

Despite the serious nature of these limitations, they can frequently be circumvented. FIGURE 1 illustrates the ingenious method used to overcome difficulties imposed by the low penetrating power of the electron beam. Imagine that we are interested in studying the crystals and bubbles in a piece of obsidian. A cross section of the fragment might resemble section S where B is the hole left





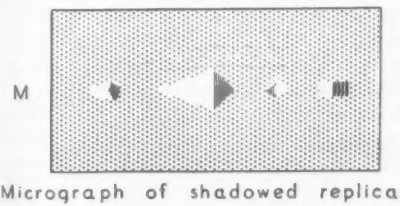


FIGURE 1. Steps in the preparation of a negative replica

by a bubble, the elevation represents an octahedral crystal projecting from the surface, and the depressions are left by crystals projecting from the fragment that has broken off. Since it is impossible to get an electron beam through "S," a replica "R" is made from it in the form of a very thin film of collodion. If the film is removed and placed in the microscope, the variation of thickness in the film will be portrayed by variation in density in the electron micrograph. Since this variation is rather slight, another technique is used to increase the contrast. The replica is placed in a vacuum and a metal, commonly chromium or gold, is evaporated so that it strikes the surface at a low angle—here 20 degrees. The metal piles up on one side of a projection and is absent in the lee of it. In the figure, point "o" is in the shadow of projection "p." When the electron beam now impinges on the shadowed replica, the contrast is sharply increased.

Shadowing also provides a means of measuring accurately the third dimension. In the case of projection "p," if the shadow cast is one micron long and the angle 20 degrees, a simple calculation shows that the crystal projects 0.3 microns above the surface.

Shadowing is also useful where objects are viewed not in replica, but directly. This is shown in PLATE 1 (C) and (D), showing particles of kaolinite from Zettlitz. PLATE 1 (C) without shadowing, shows the characteristic morphology, and by variation in density gives an indication of thickness. Some of the thinnest flakes are difficult to distinguish from the background.

In the shadowed specimen, PLATE 1 (D), the contrast is increased. In this case, the chromium impinged on the upper right of each particle or aggregate and is absent in the shadow on the lower left. Knowing the angle of shadowing to be 15 degrees, it is possible to measure the length of the shadow and ascertain that flake "A," for example, is 120 angstrom units in thickness. Flake "B" is 80 angstroms and, therefore, about 11 unit cells in height.

This illustrates how some of the limitations may be overcome, and shows why almost 75 per cent of the time spent in electron microscopy is devoted to sample preparation.

Application to Geological Problems. There are now hundreds of electron microscopes in research laboratories throughout the country, but, unfortunately, very few are used primarily for the study of geological subjects. This is a deplorable situation and

one which should soon be remedied. As this paper will indicate, there is a large amount of work to be accomplished in the high magnification phase of geological research.

Clays have been studied with the electron microscope more than any other mineral group. For one reason, the interest in these minerals has increased tremendously in the last decade; second, their size range is about right for electron microscopy; and third, samples are easily prepared and replica techniques not necessary.

Micrographs (C), (D), (E), and (F) in PLATE 1, illustrate the utility of the electron microscope in detailed morphological studies of these fine-grained minerals. Pictures (C) and (D) show the hexagonal flakes typical of kaolinite. Illustrations (E) and (F) are of halloysite, a mineral of structure and composition similar to kaolinite, but with a notably different habit. Although halloysite crystals are usually described as lath-like, our electron micrographs, such as in PLATE 1 (E), show that the forms are hollow tubes, "a," which are commonly split as in "b," which have collapsed. Double tubes are also frequently seen, as at "c" and "d." PLATE 1 (F) shows circular cross sections of similar tubes.

A story of important geological significance is told in electron micrographs (A) and (B), PLATE 2. An investigation of the micaceous minerals in the slate of northeastern Pennsylvania[4] revealed that the most abundant of these is a mineral of the hydromica or illite group. Since it is to this mineral that the slate owes its cleavage, its identity was carefully checked by differential thermal analyses, firing tests, optical data, and x-ray patterns. All of these showed that the material from the slate behaved exactly like the illite from shale that Dr. Grim has described.[5] However, a striking difference is observed in the micrograph of the illite from shale, A, and that from the slate, B. It is apparent that the very fine shreds of illite in the shale in Pennsylvania were recrystallized into much larger shreds and flakes and oriented in parallel alignment to give rise to slaty cleavage. An electron microscope study of a series of samples across the Appalachian structure, from shale to its metamorphosed equivalent, might show how the crystallinity of the fine micaceous fraction changes. Such a study would possibly shed much light upon the nature and degree of metamorphism from place to place throughout the Appalachians and other folded regions.

Micrograph (C), PLATE 2, is of interest in connection with (A) and (B), PLATE 2. From other data this mineral also appears to be an illite. It is the material which forms the Ordovician metabentonites near State College, Pennsylvania. A detailed morphological study of the illites and montmorillonites is now underway.

These two problems illustrate the study of particles under the electron microscope. The other micrographs illustrate the possibilities of the replica method. For comparison of the two methods, micrographs (D) and (E), PLATE 2, are of interest. In a study of asterism in phlogopite mica, straight transmission work proved to be ineffective. In ground flakes of the mica ((D), PLATE 2), there is some evidence of needles, but they are not symmetrically arranged and Fresnel diffraction bands obscure much of the detail. Consequently, a fresh cleavage was obtained, a drop of collodion allowed to run down over the surface and dry, the replica was removed mechanically, shadowed, photographed, and is seen in (E), PLATE 2. The inclusions are readily visible and the angle between them is exactly sixty degrees. Even many of the tiny dots fall into line. It is noticeable that some of the needles are unusually large and that material which normally would form many minute needles has gone into their formation, leaving the surrounding area smooth and devoid of inclusions. Probably such a phenomenon accounts for the common zones in phlogopite which do not show asterism. The area in the upper left corner bordering the large crystals would be such a zone on a very small scale.

Electron micrographs (F), PLATE 2, and

(A) and (B), PLATE 3, illustrate a study of crystals and bubbles in opal glass.[6] They are included here because similar studies on natural and artificial glass are of mineralogical and geological significance.

PLATE 2, (F), represents the broken surface of a typical glass containing fluorite as the solid phase. The crystals are well developed octahedrons or cubes, or combinations of both. The streak in the matrix appearing on the same side of each crystal results from breakage of the glass.

PLATE 3, (A), illustrates a sodium fluoride glass which shows a characteristic grouping of crystals and "globules" in a matrix dotted with bubbles.

The dendrites shown in PLATE 3 (B) are common in many of the glasses studied. Several features are of interest. Bubbles are found in the dendrites at the tips of the "branches." The fracture of the glass in the vicinity of the dendrites is smoother than that of the matrix in general. In several cases, the branches terminate in four-sided polygons of distinctive shape.

The same technique used on obsidian (PLATE 3 (C)) reveals at high magnification some of the crystallites which, in the form of feathery shadows, have long been observed in the light microscope. Work of this kind would be particularly significant from the standpoint of the investigation of devitrification and crystal growth.

The remaining electron micrographs show other subjects of general geological interest. To investigate carefully the possibilities suggested by each would require a large amount of careful work with both the light and electron microscopes. PLATE 3, (D), pictures the structure of calcite on a polished and etched longitudinal section of Belemnites. It is quite possible that much of the detail was produced during polishing of the section.

PLATE 3 (E) is a micrograph obtained from a fractured surface of milky quartz. The significance of the structure is unknown but there are many like it in the specimen. No bubbles were observed.

PLATE 3 (F) illustrates a replica of the face of a smoky quartz crystal after light etch with hydrofluoric acid. A growth line on such a face becomes a growth "zone" under the electron microscope. The structure brought out by the etching is suggestive of a very fine-grained aggregate. A careful study combining electron microscope and electron diffraction techniques might shed much light on the problem of the smoky color in this type of quartz.

PLATE 4, (A), (B), (C), (D), constitutes a series of electron micrographs of a fractured surface of novaculite, the fine-grained silica rock. The initial magnifications in the electron microscope were 2,000, 4,500, 7,000, and 10,500×. The siliceous ooze from which this quartz is formed apparently crystallizes into particles which in some cases appear to have crystal faces.

These micrographs illustrate a few of the possible applications of the electron microscope to geological research. It is apparent that this instrument will open many avenues of research that have heretofore been closed. Sorby was commonly faced with the criticism that it was impossible to look at a mountain through a microscope. The electron microscope has made the mountain 100 times bigger, but just as the light microscope has become standard equipment in all phases of geology, so the electron microscope will soon be taken for granted as a powerful geological research instrument.

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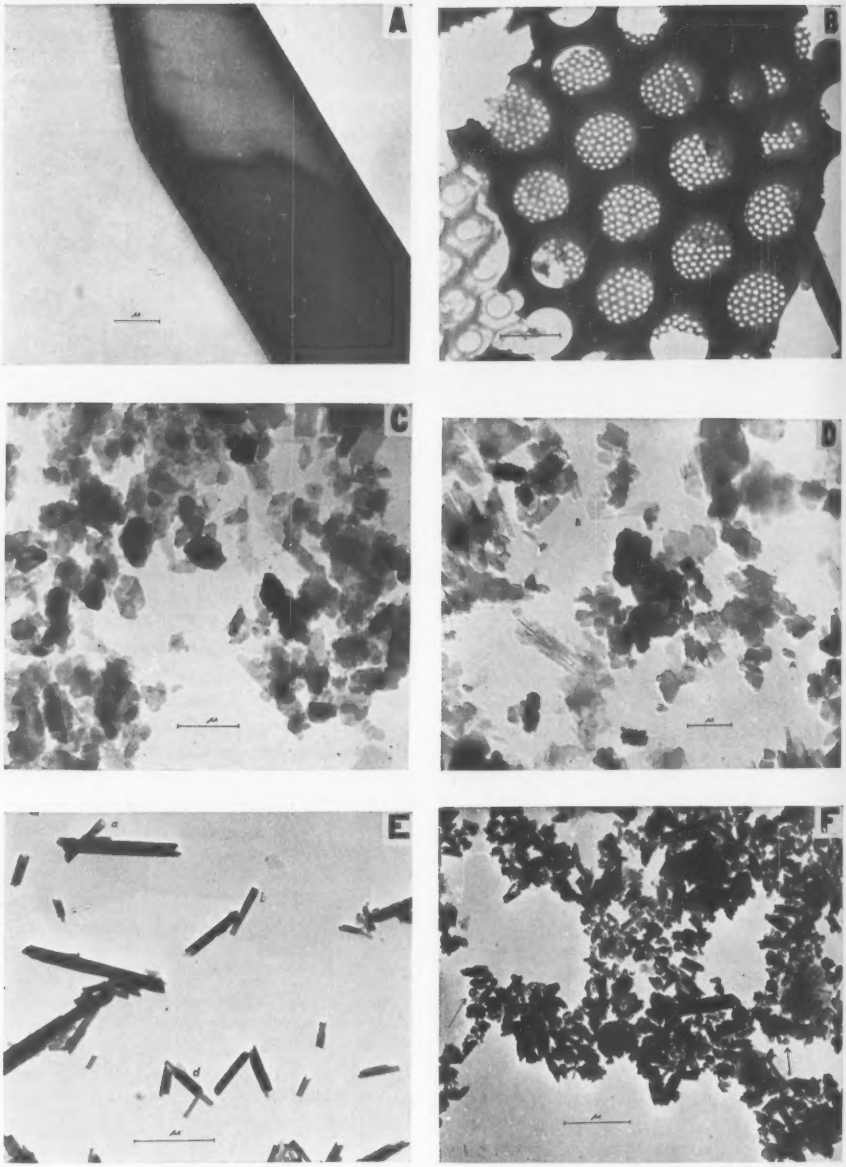

PLATE 1.

A. Collodion film.
B. Diatomaceous earth; Santa Barbara County, California.
C. Kaolinite, unshadowed; Zettlitz, Austria.
D. Kaolinite, shadowed; Zettlitz, Austria.
E. Halloysite; Real County, Texas.
F. Halloysite; Beuthen, Silesia.

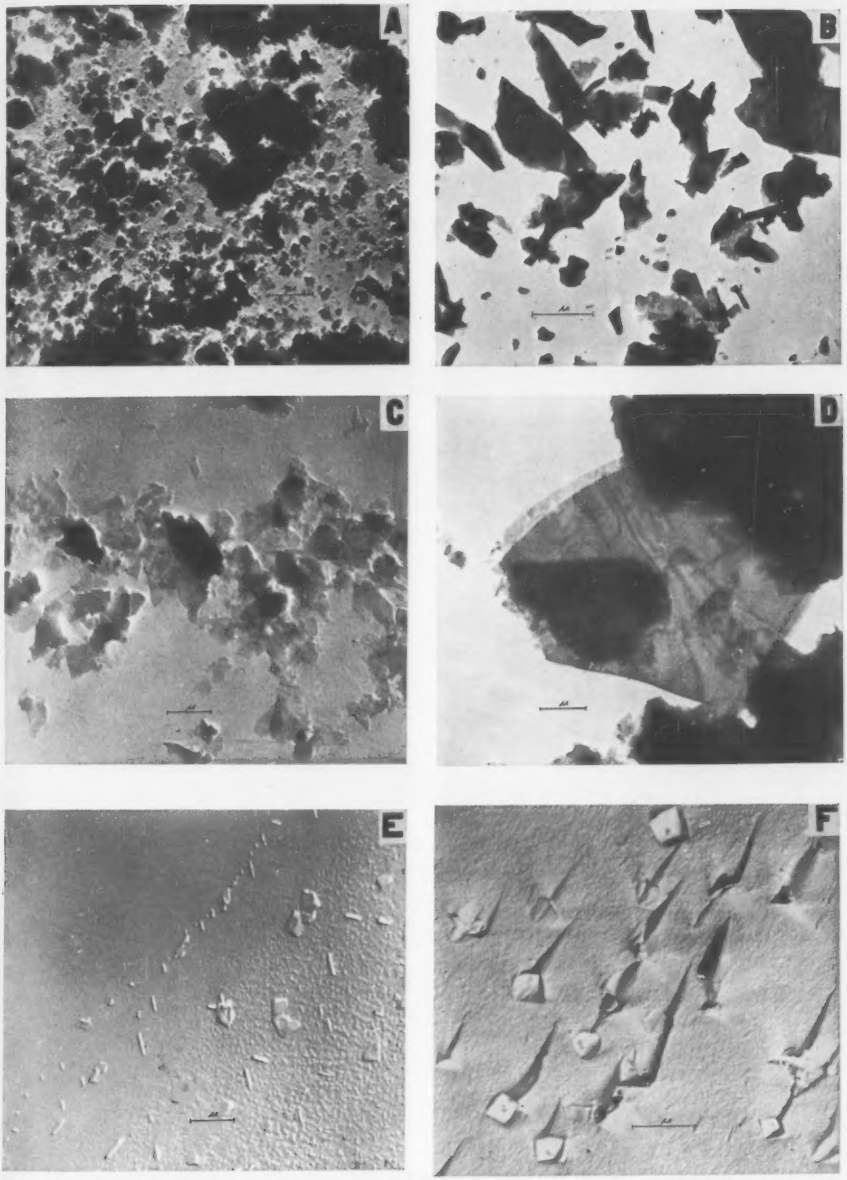

PLATE 2.

A. Illite from shale; Fithian, Illinois.
B. Illite from slate; Pen Argyl, Pennsylvania.
C. Metabentonite mineral; Lemont, Pennsylvania
D. Phlogopite mica particles; Quebec, Canada.
E. Replica of phlogopite mica surface; Quebec, Canada.
F. Fractured surface of fluorite opal glass.

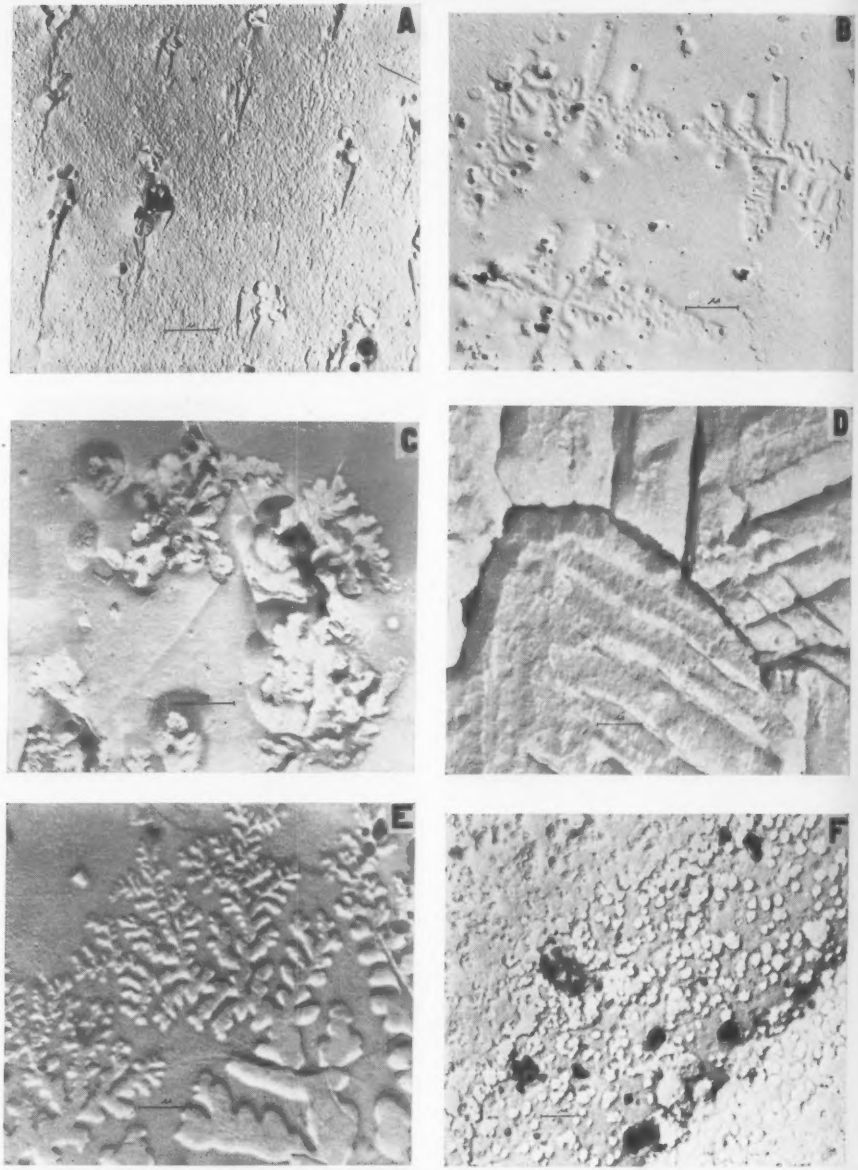

PLATE 3.

A. Fractured surface of sodium fluoride opal glass.
B. Dendrites in opal glass.
C. Crystallites in obsidian; Bombardos, Greece.
D. Calcite structure in longitudinal section of Belemnites.
E. Fractured surface of milky quartz; Dillsburg, Pennsylvania.
F. Crystal face of smoky quartz etched lightly with HF; St. Gotthard, Switzerland.

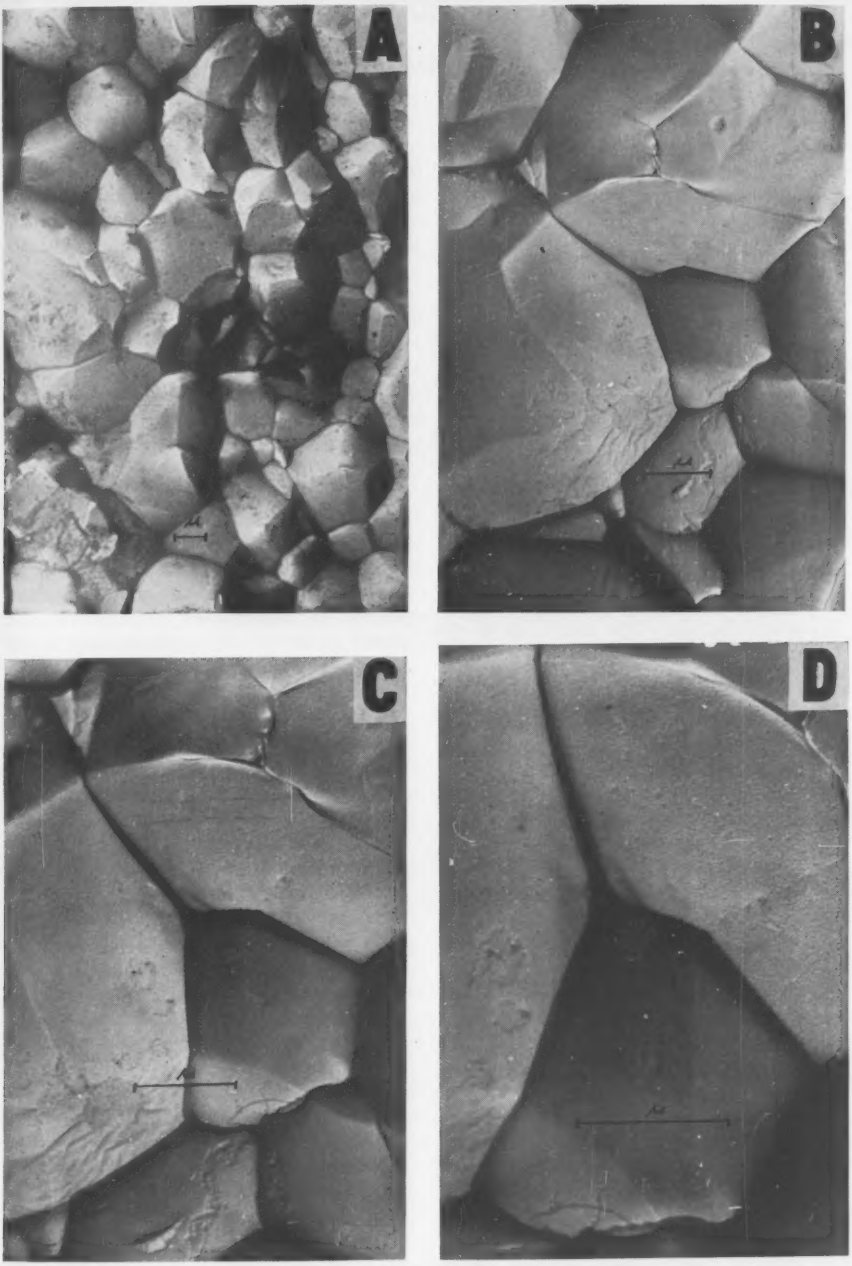

PLATE 4.
Fractured surface of novaculite; Hot Springs, Arkansas

SECTION OF BIOLOGY

A.T.P.-ASE ACTIVITY IN EMBRYONIC DEVELOPMENT

L. G. BARTH*

The basic problem which is considered in this paper is the problem of differentiation. There are two aspects of this problem. First of all, an external stimulus is necessary to convert an undifferentiated cell into a differentiated cell. This can be done in a variety of ways. In studies on the determination of the polarity in hydroids, it is found that polarity may be determined by imposing a hydrogen ion concentration gradient across a stem of the hydroid. Similarly, in the egg of *Fucus* (Whittaker), the polarity of the egg can be determined either by hydrogen ion concentration, by an electrical current, or by light. Another type of external stimulus that will determine differentiation is that resulting from embryonic induction. The induction of the neural plate can be brought about by a variety of artificial agents. The substitution of various dead tissues for the amphibian organizer falls into this classification. Here, too, must come the various carcinogenic agents which when applied to skin will cause cancer. These are all external stimuli which change the characteristics of the cell so that it becomes different from its previous state.

The second aspect of differentiation is an internal change in chemical composition. This results from the external stimulus. We would like to know what is the first indication, the first change in the cell after the stimulus is applied. An internal chemical change is inferred from embryological work. We know that before there is any visible differentiation in a cell, it has acquired chemodifferentiation. This can be shown by transplantation and the resultant self-differentiation of the cells in a foreign environment.

What is the general nature of this internal change, this chemodifferentiation? In the first place, it must be an irreversible change. Once the amphibian organizer has induced the ectoderm toward the formation of a neural plate, then that ectoderm may be removed from the action of the organizer and it will go on and form a neural tube. It can be exposed to other inductors and will no longer respond. Therefore, this change, to some extent at least, is irreversible.

The second aspect of this internal change is that it must be an internal rearrangement of the chemical compounds in the cell, because nothing new is added when the cell differentiates. The evidence for this statement is indirect and resides in the fact that a variety of chemical compounds, many of them not normal cell constituents, will induce a neural plate in the amphibian ectoderm. An abnormal cell constituent cannot persist in the cell and therefore must act by producing a rearrangement of compounds already present.

To go on with this background, the rearrangement of these cellular constituents during the early phase of differentiation could be release of a compound from an inactive state. Thus, substances responsible for neural differentiation may possibly be bound in an inactive form in the ectoderm. The organizer would then be an agent which liberates this compound. The initial change could also be the formation of a new compound by a regrouping of components of the cell. A protein or enzyme might adsorb another ion or molecule and, thus, form a complex which may have new properties.

A third possibility is that a shift in equilibrium among the various components of the cell may result in an increase in the concentration of the compound which is responsible for differentiation. This would call for a picture of the undifferentiated ectoderm as containing all the compounds for the differentiation of nerve, epidermis, notochord, muscle, *etc.* These substances would be in

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This paper, was presented at the meeting of the Section on January 10, 1949.

an equilibrium such that no one predominates. When the neural inductor stimulates ectoderm, then the chemical reactions giving rise to neural substances are favored and the rest break down and are converted to neural substances. A competition between various reactions may result in a suppression of all the modes of differentiation except one. An example of competition may be taken from experiments on the hydroids. Both ends of the stem of a hydroid *can* form hydranths. In terms of differentiation substances, all the substances are present. Only one end *does* form a hydranth, however, when the two ends are in competition with each other. One end forms a hydranth and the other end a stolon. Both ends can form hydranths if we interpose a ligature between the two ends. If this type of competition can be extended to reactions within a cell, then a cell may be able to form a neural, epidermal or muscle cell, but if an external substance which will favor one reaction as opposed to another is added, then a shift in one direction would occur.

All this leads, of course, to the supposition of differentiation substances responsible for the differentiation of the cell, and in any case, regardless of their origin, we want to know what these substances are like. The substance must be self-duplicating in order to maintain the cell type under a variety of external conditions. A self-duplicating unit of some sort must form in the cytoplasm which will continue to duplicate itself more or less independently of the environment. If these substances are self-duplicating, then they need an energy source. The ultimate source of energy must reside in cellular oxidations. And, finally, there must be some linkage between cellular oxidations and the self-duplicating substances—a transfer of energy between the actual oxidation in the cell and the self-duplication of the compound within the cell.

Turning to specific examples, we ask what the energy source is in the case of the frog egg. It has been known for many years that glycogen disappears during early embryonic development in the frog egg. The steps in the breakdown of glycogen appear to be very similar to the steps in glycogen breakdown in muscle. In the first place, a triose-phosphate-dehydrogenase is present in the frog egg, as shown by Brachet and Rapkine. In the second place, lactic acid is formed under anaerobic conditions and development takes place at the expense of lactic acid formation and an oxygen debt. Third, phosphocreatine is present. These studies, in addition to some work dealing with a block to respiration in hybrids, led us to the general idea that perhaps the same type of phosphorylating glycolysis is present in the frog egg as in muscle, in which case the terminal step would be the formation of A.T.P.

Studies on phosphorylation in the frog egg showed that the A.T.P. concentration does not change very much with development. That is, the absolute amount of A.T.P. during cleavage, gastrulation and neurulation is about the same. This situation might be expected if A.T.P. were part of a system for the transfer of energy from the oxidations to some acceptor in the cell. If the frog egg is placed under anaerobic conditions, then the A.T.P. breaks down and inorganic phosphate appears. Under these conditions, the gastrula continues to develop with the concentration of A.T.P. dropping from about 25 gamma per 100 eggs to about 16 gamma. Now, this breakdown of A.T.P. under anaerobic conditions probably also occurs under aerobic conditions; but, with the cellular oxidations intact, the A.T.P. is constantly resynthesized so that its concentration does not change. The resynthesis of A.T.P. can be shown by first exposing the eggs to anaerobic conditions, where the A.T.P. breaks down, and then readmitting oxygen into the system, in which case the A.T.P. is then built up again to its normal concentration. This resynthesis of A.T.P. after breakdown is very rapid. After about 22 hours exposure to nitrogen, during which time A.T.P. breaks down, recovery occurs within about two hours.

Thus, the development of the egg under anaerobic conditions appears to be at the

expense of breakdown of A.T.P. and, when oxygen is readmitted, the A.T.P. is synthesized again to its normal level. Now, if A.T.P. is the link between respiration and development, there must be some means of shunting the energy from A.T.P. to the various processes of differentiation. There must also be various acceptors of the energy-rich phosphate. And, thus, we look for a group of enzymes which will release and transfer phosphate from A.T.P. to the various acceptors in the cell. These acceptors would then be the differentiation substances which we assumed earlier in this discussion. On the basis of economy of hypothetical substances, we might assume that the enzymes which act on A.T.P. are the actual differentiation substances themselves. That is, the enzyme which breaks down A.T.P. may also accept the phosphate and in so doing perform work in the cell. This situation is not without precedent, because a similar situation was formerly postulated for muscle. Myosin was considered to be A.T.P.-ase. In a sense, that is still true. However, myosin turns out to be a rather firm complex of several proteins; and perhaps differentiation substances within the cell may turn out to be a complex of several proteins which act as a unit. In any case, the role of enzymes which act on A.T.P. would appear to be important.

Following the procedures worked out for muscle, protein extracts which liberated inorganic phosphate from A.T.P. were obtained. Since a water-soluble enzyme from potato had been reported, we tested water extracts from the egg and found high A.T.P.-ase activity in water as well as myosin extracts. Finally, extracts were made in 10 per cent NaCl at pH 6.9 because under these conditions myosin was reported to be relatively insoluble. We wanted to see what the A.T.P.-ase activity was in an extract that does not contain myosin. This gives us three protein fractions, each of which yields A.T.P.-ase activity. These three extracts have different properties.

If we plot the activity of the extracts during cleavage, gastrulation, and neurulation, the activity of all three extracts is low during cleavage. The water extract shows an increase in activity up to gastrulation and it begins to fall off after gastrulation. The 10 per cent NaCl extract starts low and increases, but does not fall off during the interval from gastrula to neurula as does the water extract. The myosin-like extract starts off rather low and is always lower than the water and 10 per cent NaCl extracts.

These three extracts differ in their activity at different hydrogen-ion concentrations. The water extract shows a regular increase in activity with increase in pH and is very high around pH 9.0. The 10 per cent NaCl extract shows a more complicated pH curve with an optimum at pH 7.0 and a second one in the alkaline range, around pH 8.8–9.0. Thus, there are two peaks of activity in this extract. The activity of the KCl extract increases as the solution becomes more alkaline.

The activity, with respect to time of incubation, shows the water extractable enzyme to be a very stable system which does not fall off after an hour of incubation. Some of the extracts from mammalian tissues show a very sharp decrease in activity with respect to time. The 10 per cent NaCl extract begins to fall off after about 10 to 15 minutes, and the KCl extract falls off very rapidly with respect to time. The latter is the most sensitive A.T.P.-ase of the three, with respect to temperature.

From these observations, three different A.T.P.-ases were indicated to be present in the frog egg. Of course, there is always the possibility of a single enzyme combined with different proteins, and, therefore, having some different properties. Indeed, some studies of these three fractions from adult frog tissues showed that the NaCl and KCl extracts possessed identical pH curves. That is, in the adult, the A.T.P.-ase activity, with respect to pH, is low at pH 5.0, has one optimum at about 6.0, another at about 7.0, and then a much higher optimum at 8.8–9.0. The KCl extract showed the same optima but the curve was shifted somewhat. Thus, in the adult, the extract with 10 per cent NaCl and 0.5 M KCl seemed to be identical. The water extract, however, shows a

quite different curve with an optimum at about 7.0–7.2.

It is interesting that the A.T.P.-ases in the adult show different characteristics from those of the embryo. The pH curve of the NaCl fraction in the embryo has an optimum at 7.0 and another at pH 9.0. Two of the three optima of the adult are present, but the third is lacking. It would look as if during embryonic development the 10 per cent fraction acquired another optimum at pH 6. Some change must have occurred during development. That change occurs in the early tadpole. In the tadpole, the optimum at pH 6 is present. Another difference between embryo and adult extracts is in the pH characteristics of the water extract of the embryo, which is low at pH 5.0, and increases rather steadily to pH 9. Whereas, in the adult, the water extract starts low, reaches a maximum at pH 7.0, then falls off. Evidently, we are dealing with different A.T.P.-ases in the embryo and adult.

Considering the evidence so far, the work on the frog indicates that A.T.P.-ases play a role in development as a whole. A.T.P. is necessary for development under anaerobic conditions, A.T.P.-ases are found during development, and they increase in amount. Thus, there is some relationship between A.T.P. and development as a whole. But in development of the whole egg, many processes occur besides differentiation—cell migrations and foldings of layers, in which physical work is done. There is also a general growth process, a synthesis of new protoplasm taking place when an egg develops, so that we cannot relate these A.T.P.-ases directly to cellular differentiation. We look, therefore, for a system in which growth and cell migration are lacking and try to find one in which differentiation predominates.

This situation was found in a colonial ascidian at Bermuda. This ascidian reproduces asexually by budding from a stolon such that at fairly regular intervals a zooid forms. If the stolon is cut at any level and a piece removed, an outgrowth develops from each end. Buds form and differentiate into zooids. This differentiation of the stolon into zooid can be controlled.

In the first place, these pieces of stolon exhibit what is known as a group effect, described by Whittaker for the egg of *Fucus*. This is a phenomenon in which several individuals placed in close proximity, in a geometrical pattern something like spokes of a wheel, have a mutual effect on each other. The stolon grows outward from all ends, but the buds and young zooids only form from the peripheral ends. Thus, a mutual inhibition of the ends which are in close proximity is obtained. The stolons migrate and fuse to form a complicated network within which the circulations of the individuals intermingle freely. Something accumulates in the central area which prevents the formation of zooids, without however, interfering with the development of the stolon.

The simplest assumption is that excretory products—carbon dioxide, urea, uric acid—accumulate at this point and inhibit development of the zooids. These three agents were tested in a gradient chamber which consisted of a reservoir for the agent and a large surrounding free space. From this reservoir carbon dioxide, for example, diffused and came in contact with one end of each of these stolons, and the other end was bathed by sea water. Under these conditions, stolons will grow from the end exposed to carbon dioxide, but the zooids form only from the free ends.

Thus, the stolon represents a mass of undifferentiated cells, in the sense that any group of cells within the stolon may form a zooid. In addition, differentiation can be controlled by an external chemical stimulus. The equilibrium between the zooid and the stolon can also be controlled by temperature. If a zooid attached to a stolon is placed at 28°C., the cells from the zooid break off from the various organs and accumulate in the stolon. The stolon becomes very thick and packed with cells. The phenomenon has been called regression and was discovered very early by Driesch. It was re-

examined by Huxley and recently by Deviney.

If the stolon is now transferred to 22°C., the process will reverse and a zooid will differentiate from the cells of the stolon. The system can undergo regression, in which all morphological differentiation is lost, and then can undergo differentiation once more. The cycle can be repeated several times.

How does the A.T.P.-ase activity correlate with this regression and differentiation? Here no growth processes occur to speak of, no synthesis of new protoplasm. The cells are already formed. For the most part, there seems to be a change from a spherical, undifferentiated cell in the stolon to the differentiated cell in the organs of the zooid. Zooids were cut off from the stolons and investigated for A.T.P.-ase activity. The water extract yields high A.T.P.-ase activity from the differentiated zooid. From the stolon, however, little or no measurable A.T.P.-ase activity was found. If we take these stolons and put them at 22°C., as soon as the buds come out, the A.T.P.-ase activity begins to shoot up very sharply. The A.T.P.-ase activity of water extracts was measured at different times, beginning with the completely regressed zooid in the stolon and during bud formation and differentiation of the buds into a zooid. The activity is very low at first, and then shoots up very sharply. The first change in the stolon is the formation of outgrowths from the two ends. These advance along the bottom of the dish. When spherical buds form at both ends the A.T.P.-ase activity rises sharply.

Thus, we find that the A.T.P.-ase activity disappears when the zooids lose their organization and reappears when they reorganize into a new zooid. A structural dedifferentiation is accompanied by a biochemical dedifferentiation.

Since the formation of the zooid can be controlled to some extent by external factors, it brings up the question of the possible correlation between the factor which determines the polarity of these forms and the activity of A.T.P.-ases. Carbon dioxide, as we pointed out, represses the formation of the zooid at one end. Of course, there are a number of interpretations as to what carbon dioxide does. It is interesting that the pH optimum of all A.T.P.-ases is well on the alkaline side. The pH of the cell is not known, but carbon dioxide-saturated sea water is about 5.0. Carbon dioxide does penetrate cells, as we know from permeability studies, and, by making the cell acid, may lower the A.T.P.-ase activity.

In summarizing these results, we can say that A.T.P. is present in the frog egg, and that it breaks down when energy is needed, as in the case of anaerobic conditions. We also know that as development proceeds in the frog egg, enzymes which split A.T.P. do appear in greater and greater concentration. And finally, from this last work we can say that during the process of morphological dedifferentiation the A.T.P.-ase activity disappears and reappears when differentiation takes place once more. These few facts suggest that A.T.P. is an energy source for differentiation.

DIVISION OF MYCOLOGY

A NEW METHOD FOR THE EVALUATION OF ANTIFUNGICIDAL CHEMICALS

By SAMUEL M. PECK*

New fungicides are evaluated according to certain standard procedures. There are excellent *in vitro* techniques which give data concerning the necessary concentrations and the rapidity by which the fungicides kill various pathogenic organisms. Thorough toxicity studies are necessary before clinical trial is attempted.

While clinical evaluation is time-consuming and expensive, no *in vitro* method can take its place. Too often, however, the clinician is confronted by discrepancies

* Dermatologic service of the Mount Sinai Hospital, New York. This paper was prepared with the assistance of Rose Bergamini and presented at the meeting of the Division on January 28, 1949.

between the laboratory data and clinical effectiveness.

A useful fungicide must not only have a high index of clinical cure, but there must be a minimum of irritation from its use. This irritation is either primary or due to sensitization. When the irritation is primary, because of the necessary effective concentration, the fungicide cannot be used in contact with living tissue. Such a factor is quickly evaluated. The irritation due to sensitization is of two types. When sensitization is due to an idiosyncrasy of the fungicide itself, we have well established procedures which give us reliable information concerning the sensitizing index of any chemical.[1] The second type is based on a different mechanism which will be described.

In most clinical applications of fungicides, we are dealing with infections of the skin or hair. Because of this, the evaluation of any fungicide must take into consideration the special and specific conditions which are present in most of these fungus diseases. The majority of the fungus infections which we are called upon to treat are those due to the dermatophytes; and of these, dermatophytosis of the feet (athlete's foot) is the most common.

Enough statistical data[2] are available to show that more than 75 per cent of the population, depending on the age group and the season of the year, will show active clinical evidence of dermatophytosis of the feet. Of these, more than 50 per cent will develop various degrees of sensitization to fungi and or their products. In many instances this sensitivity is accompanied by allergic manifestations which are known as dermatophytids.

It is the common experience of the clinician that, even with fungicides which are not primary irritants and, apparently, have a low index of sensitization, irritations are often encountered. These symptoms are due to the second type of allergic reactions, which are seen during the course of treatment with fungicides and are not due to the sensitization to the fungicides themselves. Such allergic phenomena are due in most instances to active precipitation of allergic reactions of the dermatophytid type.

The explanation for their occurrence has been that, just as in the Herxheimer reaction in syphilis, the fungicide causes a rapid destruction of the fungi which in turn causes a sudden release of toxins or antigen. In the sensitized individual, the "id" reaction results. Apparently no one has suggested the possibility that the fungicide itself may actually stimulate the formation of antigens by the fungi.

An ideal fungicide, then, would be one which is not primarily irritating, which has a low sensitization index per se, which suppresses the growth of the fungi, and which, at the interphase between fungicidal and fungistatic activity, does not stimulate the pathogenic organisms to produce antigens.

We believe that, in the method which we are about to describe, the last factor can be evaluated.

Materials and Methods

Our method is based on the study of the effects of addition of fungicides on the production of trichophytin. Trichophytin is the watersoluble antigen found in the pellicle and the filtrate of a culture of fungi on Sabouraud's bouillon. It has been shown by many investigators that the positive skin reactions following the intradermal injection of trichophytin is due to a specific sensitivity resulting from a fungus infection. Trichophytin has been identified with the specific sensitizing factors which are elaborated by the fungi in the course of the infection and are responsible for allergic reactions or dermatophytids.[3]

The usual procedure for the preparation of trichophytin consists of inoculation of Sabouraud's bouillon with trichophyton gypseum or trichophyton interdigitale contained in a large Erlenmeyer or Roux flask at a pH of about 6.5 to 6.7. Growth is allowed to proceed at room temperature for ten to twelve weeks until a large surface pellicle is formed. The pellicle is then triturated with sand in the mortar after preliminary freezing with solid carbon dioxide. A sufficient amount of the bouillon is added to make a

slush. The semiliquid mass is placed in the shaking machine for 24 hours. It is then kept in an incubator for another 24 hours and again shaken for 24 hours. The mass of growth in broth is then filtered through several thicknesses of filter paper and the filtrate is passed through a Seitz filter. The final filtrate has to be diluted before use in order to avoid non-specific reactions. This is the usual commercial trichophytin as it is now available for diagnostic and therapeutic purpose.

A modification of the routine method for the production of trichophytin is used in our laboratory.[5]

It has been shown in previous communications that T. gypseum was capable of producing a more alkaline pH in Sabouraud's bouillon when grown on a medium with an initial pH of 4.0 to 8.0. At an initial pH of 9.0 to 10.0 the organism acidified the medium. We could show that there was a relationship between the changes in the hydrogen ion concentration of Sabouraud's bouillon and the appearance and the concentration of the skin test factors (trichophytin). The skin test principle was apparently formed in minimum quantities or not at all as long as the pH kept dropping, but the concentration of this factor roughly paralleled the rise in the hydrogen ion concentration. Once this rise in pH takes place, enough trichophytin is formed in the bouillon to compare favorably with the long drawn out procedure which is routinely used. A rise of pH of only 2 on the acid side will give enough trichophytin in as short a period of time as ten days.

Sabouraud's bouillon, used in our experiments, was prepared by adding 40 grams of dextrose and 10 grams of neopeptone (Difco) to 1 liter of distilled water. It was then placed into an Arnold sterilizer for ten minutes and finally filtered through Watman's No. 4 filter paper while the solution was still hot. One to 10,000 merthiolate was added as a preservative.

The Sabouraud's bouillon was inoculated with T. gypseum; the same strain of organism was used throughout the experiments. A ten days' culture of T. gypseum on a slant was used. A few cc. of saline were added, shaken vigorously, and 1 cc. of the resultant spore suspension was used for inoculation into each flask. One hundred cc. of Sabouraud's bouillon was usually used in each flask. In some of our experiments, only 20 cc. were used. There were a number of control flasks for each experiment.

pH readings were taken at frequent intervals to determine the changes in the hydrogen ion concentration. A Beckman pH meter using glass and calomel electrodes (mild mercurous chloride) was used for the pH determinations. The flasks used to grow the organisms were constructed with a side neck at the base. This allowed frequent milkings with a minimum danger of contamination, and samples were taken equally at intervals of 7, 14, and 21 days.

The fractions were tested for their trichophytin content by the usual intradermal trichophytin technique. In this test, a dilution of trichophytin is used which is known not to give non-specific reaction. It is usually necessary to dilute the bouillon as we have prepared it in our experiments 1–20 or 1–30, using a standard trichophytin made in our laboratory of known potency as a control. One-tenth cc. are injected intradermally. The reaction is read in from 48 hours and sometimes up to five days for delayed reactions. A positive reaction is characterized by an area of redness and induration 1 centimeter or larger in diameter. In well defined reactions, papules and vesicles may be in the area of redness. Reactions several centimeters in diameter are not unusual. Sometimes, the reaction does not appear for four to five days and is known as a delayed reaction. The reaction may last for a week or longer and gradually disappear with scaling. It is analogous in many respects to a tuberculin test. It is usual to grade the reactions from 1 to 4 plus. The same concentration and amount of Sabouraud's bouillon is injected at the same time to determine the rare sensitivity to Sabouraud's bouillon itself.

Six to twelve patients were used in each

series of tests for each fraction, so that negative as well as positive reactions were present in each series. In this way, non-specific reactions as well as specific reactions could be evaluated. The concentration of trichophytin in any one flask was determined by the comparative reactions in sensitive patients to equivalent concentration of the filtrate from bouillon cultures containing the fungicides as compared to the filtrate from control flasks.

Experimental Part

In the following series of experiments, we will attempt to give typical examples of our experiences of the evaluation by our method of some of the old and well known fungicides as well as some of the newer ones.

Iodine:

To each of three flasks containing 20 cc. of Sabouraud's Dextrose bouillon there was added 1 cc., 0.1 cc.. and 0.01 cc. of a 2 per cent alcoholic iodine solution. Each flask was then inoculated with 1 cc. of spore suspension of a ten-day-old culture of T. Gypseum.

Results:

Iodine is very little soluble in water. There was a definite effect on the growth of the organisms by the iodine in each of the flasks as compared with the control. At the end of fourteen days, there was a definite suppression of growth in all of the flasks containing the iodine. In spite of this the concentration of trichophytin found in any of the flasks at that time was greater than that found in the control flasks which had a more abundant subsurface and surface growth.

Sodium Benzoate:

To three flasks, each containing 20 cc. of Sabouraud's bouillon there was added 1 cc., 0.1 cc., and 0.01 cc. respectively, of a 30 per cent aqueous solution of sodium benzoate. One cc. of the same spore suspension as above was added to each of the flasks.

The addition of 1 cc. of 30 per cent aqueous solution of sodium benzoate inhibited growth. There was some retardation of growth in the flask containing 0.1 cc. and the growth did not differ from that in the control in the third flask.

The pH changes in each of the flasks paralleled the degree of growth. As was to be expected, there was no trichophytin formed in the flask in which there was no growth. In the second and third flasks, practically the same amount of trichophytin as in the control was found.

Sodium Undecylinate:

To each flask containing 100 cc. of Sabouraud's bouillon, there was added 0.05, 0.23, 0.5, 1 mg., 2 mg., and 5 mg. of sodium undecylinate, respectively. Each flask was inoculated with the spore suspension as previously.

There was no growth of fungi when 2 mgs., or more, of sodium undecylinate were added. When no growth was visible, there was no change in the pH of the bouillon and no trichophytin could be demonstrated. In the flask which contained 1 mg. of sodium undecylinate, there was scant subsurface growth at the end of 21 days. The pH changes were slow in developing and there was a moderate rise in the hydrogen ion concentration beginning with about the 14th day.

The addition of 0.5 mg. sodium undecylinate to 100 cc. of Sabouraud's bouillon had a fungistatic effect. Subsurface growth was evident on the 14th day. This increased in amount slowly, but at the end of 21 days there were still no surface pellicle. A moderate amount of trichophytin, less than that found in the control flasks, could be demonstrated on the 14th and 21st days.

The addition of 0.2 mg. of sodium undecylinate still exerted an evident fungistatic effect, but not so much as when 0.5 mg. were added. However, there was as much trichophytin formed in this flask as there was in the control flasks.

Here, we have a fairly good fungicide. The concentration of trichophytin depends on the degree of growth of the fungi. However, with lower concentrations of sodium undecylinate, the concentration of tri-

chophytin formed was greater than was to be expected from the degree of growth seen.

Sodium Propionate and Sodium Caprylate:

To 100 cc. of Sabouraud's bouillon, a mixture of 5 mg. of sodium propionate and 5 mg. of sodium caprylate was added. There was a definite retardation of growth as compared to the control. The pH changes were reflected in the degree of growth. The trichophytin formation was apparently less than in the control flasks for the same period of time. Here, as compared to the sodium undecylinate, there was apparently even less trichophytin formed than in the same comparative amount of growth. The formation of this complex antigen seemed to be depressed.

Boric Acid:

To 20 cc. of Sabouraud's bouillon in each of three flasks, there was added 1 cc., 0.1 cc., and 0.01 cc., respectively, of a 1 per cent aqueous solution of boric acid. While 1 cc. of boric acid showed a marked retardation of growth, at the end of 14 days there was more trichophytin formed in that flask than in the control flasks which showed much more growth. When 0.1 cc. of boric acid was added there was moderate retardation of growth at the end of 14 days and the trichophytin formed was still more than the control. When 0.01 cc. was added to the flask, there was apparently a stimulus to growth. The trichophytin concentration was increased as compared to the control.

Boric acid, evidently, according to our method of evaluation, is a poor fungicide.

Amorphous Penicillin G:

To 100 cc. of Sabouraud's bouillon in each of two flasks, 300,000 units and 100,000 units, respectively, of amorphous penicillin G, were added. Spore suspension was added in the usual way. Growth was retarded in both flasks until the 21st day. At that time, subsurface growth became evident in the flask containing the 300,000 units. The trichophytin formation was minimal. There was some subsurface growth at the end of 21 days in the flask containing the 100,000 units—more than in the flask containing the 300,000 units. The pH curve began to rise about the 21st day, but no trichophytin was formed.

Crude Penicillin:

In this experiment, crude calcium penicillin, obtained through the kindness of Lederle, containing 310 units per mg. was used. To flasks, each containing 100 cc. of Sabouraud's bouillon and inoculated with the spore suspension in the usual way, there was added 1, 3, and 5 grams, respectively, of this crude penicillin. To two other flasks, there was added 3 and 5 grams of this penicillin, respectively, but prior to its being used, the penicillin was heated in a water bath for three hours at 57 degrees centigrade to destroy any penicillin activity.

In the flask containing the 1 gram of unheated penicillin, scant subsurface growth was evident at the end of 23 days. There was no rise in pH. There was a marked reduction in formation of trichophytin. In the flask containing 5 grams of unheated penicillin, there was no evidence of growth, no change in the pH curve, and there was no trichophytin formed.

In the flask containing 3 grams of the heated penicillin, there was scant subsurface growth at the end of 23 days; the pH curve was almost flat, and the amount of trichophytin was markedly reduced.

With 5 grams of heated penicillin, there was no growth, no change in pH curve, and no trichophytin could be demonstrated.

Discussion

While some interesting conclusions can be drawn concerning the experiments just cited, a great deal more work will have to be done to determine the importance of this type of evaluation of a fungicide.

There is no doubt that the determination of the changes in the hydrogen ion concentration in a culture of fungi on Sabouraud's bouillon is a very good gauge for the formation of trichophytin. The modified method for the manufacture of trichophytin suggested is time saving and apparently just as efficacious as the older methods now in use.

Iodine has been known to cause irritation in patients with fungus disease, and, in most instances, this has not been due either to primary irritation or to sensitization to iodine itself.

Experiment 1 offers a good explanation for such clinical observations. It is evident that as iodine suppresses the growth of fungi it apparently effects the metabolism of the fungus in such a manner that trichophytin formation is enhanced.

Boric acid has been an old standby as a safe treatment for the fungus infection which is accompanied by allergic manifestations. Experiment 2 indicates that it is a poor fungicide, since in low dilution it may apparently enhance the growth of the fungi and, what is more important, actually stimulates the formation of trichophytin.

Sodium benzoate and sodium undecylinate are good fungicides since the concentration of trichophytin drops as the fungus is retarded in growth.

Sodium propionate seems to bear out its clinical evaluation; namely, that it can be safely used even in highly sensitive individuals. It can be seen that the formation of trichophytin is diminished not only because the growth of fungi is retarded, but because of the effect of this chemical on the metabolism of the fungus. From this viewpoint, it is more valuable than sodium undecylinate.

In previous communications[6] it has been shown that amorphous penicillin G contains a factor or factors which retard the growth of fungi. It was shown that these factors were not analogous to penicillin G. When the amorphous penicillin is refined, these products are apparently removed. In the experiment cited here, it was further shown that apparently these factors are contained in crude penicillin and that they are not affected by heating, which further differentiates them from penicillin itself.

It is of special interest to note that these fungistatic and fungicidal agents in crude penicillin, as they retard the growth of the fungi, markedly reduce the formation of trichophytin. Apparently, we have there a very valuable agent against fungi if it can be isolated and concentrated enough to be used clinically.

Summary

A method is presented for the evaluation of fungicides which attempts to demonstrate, not only their fungicidal and fungistatic activity, but their effects on the metabolism of the fungi as far as the formation of trichophytin is concerned. This is of value since trichophytin is identified with the antigens elaborated in the course of fungus disease which are responsible for the allergic manifestations often associated with them.

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SECTION OF PSYCHOLOGY

THE ANNUAL SCIENCE TALENT SEARCH FOR THE WESTINGHOUSE SCHOLARSHIPS.*

By H. A. EDGERTON† AND S. H. BRITT‡

The eighth annual Science Talent Search has been completed and the forty winners will soon be announced. Back of this is one of the most interesting programs in which we have ever participated.

In the spring of 1942, the Annual Science Talent Search was inaugurated by Science Service, and organized as an activity of Science Clubs of America. It has been conducted annually with the administration of Science Service. The entire program, including awards to the winners, was made financially possible by the Westinghouse Electric Corporation as a contribution to the advancement of science in this country.

Its purposes are: (1) To aid in the discovery and development of scientific aptitudes of boys and girls in our high schools. (2) To aid in creating more interest and activity in science among the youth of the country. (3) To emphasize to the public the necessity of developing that facet of our human resources—scientific talent.

We wish to give a brief summary of the techniques used, some notion of how they operate, and a look at what happened to the contestants in later years.

When we were asked one morning, "How should one make such a selection as called for by the general plans of a Science Talent Search among high school seniors?" we had to do more than note that "that is a good question."

We had to find answers to these questions: (1) How does one recognize persons, now seniors in high school, who later will be creative scientists? (2) What selection techniques, adequate to the problem, can be administered satisfactorily in high schools? (3) Could the procedures be made fairly objective and such that their cost would not be prohibitive in time or labor? Then came that $64 question, to which we had to give an answer:—"What kind of person should we seek?" What was our best bet regarding the identity or description of a creative scientist when a senior in high school?

Undoubtedly, such persons should be "bright" and able to do academic work of high quality. They should have some background in science, and should have shown by their records, both in and out of school, a strong interest in science. In addition, they should have exhibited such traits as social competence, initiative, resourcefulness, and good work habits. This picture of the potential scientist suggests a person who is intellectually capable, interested in science, and a leader among his fellows. Such criteria for selection very likely have resulted in overlooking some persons who later will be leaders in science and invention, but it is believed that from an *a priori* probability point of view, they have justified themselves.

The competion is really two contests—one for boys and one for girls. It has been agreed each year that the ratio of boys to girls throughout the competition would remain constant and, also, approximately equal to the ratio of boys to girls who entered the contest.

In order to carry out a selection procedure which would have validity and also be administratively economical, the "successive hurdles" technique has been used every year. This means that all contestants must pass the first hurdle, but some will survive this hurdle and some will not; the survivors of the first hurdle then face the second hurdle; the survivors of the second hurdle go on to the third hurdle, etc., until there remain only the scholarship winners. Such a method has its maximum validity when the successive hurdles are applied in decreasing order of validity.

* This paper was presented at the meeting of the Section on January 17, 1949.
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‡ McCann-Erickson, Inc., New York.

Accordingly, the successive hurdles were set up as follows:

1. *Science Aptitude Examination.* This was to select those who have the aptitude to study science in colleges and universities, but without too heavy a premium on knowledge of science.
2. *High School Record.* To select those who have demonstrated their ability to profit from formal academic training.
3. Score on *recommendations* furnished by high-school teachers, covering such categories as scientific attitude, resourcefulness, initiative, work habits, social competence, and mechanical ability.
4. Rating on the essay submitted on the topic, "My Scientific Project."

The first three hurdles reduce the numbers of contestants to 300. The fourth, plus all the accumulated evidence, is the basis for selecting the winners—40 boys and girls who attend the Science Talent Institute in Washington, D. C., each year, hear and talk with outstanding scientists, and compete for the top scholarships. The remaining 260 of the 300 are honorable mentions, and they well deserve that honor. They are within the top 20 or 25 per cent on the examination, in the top 10 or 15 per cent of their high-school class, and have shown great interest in science, good work habits, social leadership, etc., in terms of what they have done.

Including the eighth Science Talent Search, there have been for all eight years 320 Winners, and 2,080 Honorable Mentions.

The top scholarships—2 each year—are awarded on the basis of the judgment of the contest judges. Their information includes all that available in selecting the winners, *plus* the information and opinions gained through standardized psychological interviews with the winners. Each winner is individually interviewed by each judge.

Then comes the question regarding the empirical validity of the selection procedures. Do those who were winners succeed in greater measure as scientists than those who were awarded honorable mention; and did the honorable mentions succeed in greater measure than those who won no honors at all? Then there is the additional question, "Did the identification and public acclaim produce the difference in achievement, if any, between those who were honored and those who were not?"

Each year a follow-up questionnaire is mailed to all who won honors in each of the searches, and to all contestants of the first and second searches.

A study of the questionnaires of the boys in the first Science Talent Search was reported last summer in the *American Scientist.** This study, based on the first three questionnaires, shows the following:

1. More of the honors group (called the A group) majored in Science than did the non-honors (called the B group) contestants.
2. More of the A group went to college than did the B group. Despite war conditions, each year the winners had the largest per cent in college, the honorable mentions the next largest per cent, and the others the least in college.
3. In terms of college grades, based only on those attending college (and with the problems of approximately equating marks from many colleges) the winners averaged 3.55 the second year and 3.52 the third year, (A = 4, B = 3, etc.); the honorable mentions 3.48 the second year and 3.42 the third; while the other group averaged 3.00 and 2.99. The entire group certainly has set an outstanding record. Similar data have been shown for the girls.
4. Membership in honorary societies might be a clue to outstanding achievement. At the third year, 49 per cent of the winners had become members of an honorary society, 17

* Edgerton, Harold A., Britt, Steuart Henderson, and Norman, Ralph D. "Later Achievements of Male Contestants in the First Annual Science Talent Search," *American Scientist.* 36: 403–414, 1948.

per cent of the honorable mentions, and of the other, 5 per cent had become members.

5. In terms of scholarships and fellowships, other than the S.T.S. awards, the A group has been considerably ahead of the B group.
6. Considering only the contestants' first choice of professional field, striking results are found. Considering the scientific field broadly, 73 per cent of the A group indicated some scientific area as their first choice. This includes 87 per cent of the winners. This may be compared to 55 per cent of the B group giving a similar indication.
7. The question, "What are the main things you have learned about science during the past year?" revealed that, while the differences in the responses of the A and B groups were not great, this question would become more valuable as time passes by.
8. The item, "List and briefly describe any *special* scientific or professional apparatus or other mechanical devices which you have become competent to use since January of last year," yielded no basis for distinguishing between the two groups. It is possible, though, that had the military aspects of the situation not come so strongly into the picture, involving as it did introduction of our contestants to a tremendous variety of technical and scientific apparauses, more differences would have been found between our groups. This item in the questionnaire may ultimately become more useful in the later years if, as we believe, the A group demonstrates superiority.
9. The items, "List your principal contributions in the form of publications, inventions, patents, etc.," and, "Describe any research or other special work which you now have in progress," produced no answers which distinguished between the two groups, A and B.
10. In the first year, 5 per cent of the A group and 6 per cent of the B group reported membership in one or more professional societies. In the second year 11 and 10 per cent respectively reported, whereas in the third year 17 and 13 per cent mentioned such membership. The A group thus has a slight but insignificant excess in the third year. The trend is about the same for the Winners.
11. In the follow-up study of the male contestants in the Second Annual Science Talent Search, some evidence was offered to show that selection rather than public recognition was associated with such evidences of achievement as we have just listed. Using a sample containing only the B group—no winners nor honorable mentions—there was some relationship of the selectors (test score, high-school record, and recommendations) to successes.

Using data from only the first three years of follow-up of the contestants in the First Annual Science Talent Search, we believe that boys selected by the successive-hurdles mentioned as superior in scientific aptitude tend actually to be superior in terms of several objective criteria. Of the ten criteria touched upon, six have been shown to be distinctive:—majoring in science; extent of education; college grades; honorary societies; scholarships or fellowships; and choice of professional field. The other four criteria yield no statistical significance between the ranking and non-ranking contestants, except possibly "things learned about science," which may be significant in two out of three years. However, war service should not be overlooked as an important factor with respect to the question on the use of scientific apparatus and in other criteria.

The follow-up study is continuing,—questionnaires each year. A few years from now we hope to be able to summarize the results in terms of ten years of growth of science talent.

SECTION OF ANTHROPOLOGY

SOME PRELIMINARY CONSIDERATIONS OF LARGER UNITS IN CHINESE SOCIAL ORGANIZATION

By MORTON H. FRIED*

The literature of anthropology is notoriously weak on China. This lack is being corrected at a rapid rate with such additions as the work of Fei Hsiao Tung, Chang Chih-i Lin Yueh-hua, Martin Yang, and Francis Hsu, all of whom have contributed their volumes within the past ten years. However, there is no adequate description or analysis of larger and more intricate community organizations such as larger market towns or county seats. It will be the purpose of this paper to give some general descriptive facts concerning the county seat as a discrete unit of Chinese society and from that base make some analyses of the interrelationships between such type-units and the country-side in which they appear.

The author was fortunate enough to have resided in a Chinese county seat for a period of more than a year, being supported in this field study by the Social Science Research Council. The facts given in this paper are drawn mostly from data collected in the town of residence.

Seen in a romanized form, *Ch'u Hsien* is a common Chinese place name. In the original characters there is no such confusion, the *Ch'u* character is a phonetic equivalent that has no meaning other than to designate this place. The *hsien* character is of general usage, it stands for 'county' and when combined with a place name it may mean either a county or a county seat. Thus, Ch'u Hsien means either the whole county that lies just inside the Anhwei provincial border across the Yangtze River from the national capitol at Nanking, or the seat of government of that county, an ancient walled town.

Ch'u Hsien is in the Yangtze Plain and raises rice, winter wheat, corn, cotton, and sesame as major crops, and soy beans, barley, yellow beans, kaoliang, buckwheat, and hemp among the secondary crops. There are two crop yields a year: the fall harvest being mainly of rice and corn, the spring harvest of wheat and beans. The gardens, which are quite separate from the fields, produce twelve months out of the year. However, the winter yields are small and the people of the town, as well as their rural neighbors, put out a supply of vegetables to dry. After salting, these foods are reserved for periods of winter scarcity. Pigs, chickens, ducks, and geese are kept in abundance within the town and dogs are common. No water buffalo are present except those which are being kept for market, there being no use for such animals in the town. Burros, while frequent in the countryside, are used in the town only for turning grindstones and they appear in the shops of oil producers or the millers of corn.

The landscape of the town is, of course, quite different from that of the countryside. Ch'u, in particular, is a most beautiful spot with its aged walls and three hoary pagodas. But in addition to the normal difference in contour due to a variation in building types, there is a notable change in the appearance of the land. As one approaches a town or city he can see the paddy fields give way, quite suddenly, to the small strip gardens that characterize Chinese horticulture. The systems of cultivating gardens differ markedly from those used in the fields. These differences are reflected in many ways: linguistically, in the use of a separate specialized vocabulary for each; in social structure, by the existence of a separate guild for each; the contrasts between these two organizations; and by the contrasts in division of labor within the respective families of a farm and a garden. There are many additional points of dissimilarity, tools, standard of living, land ownership, and daily routine, but such a discussion lies outside the present paper.

The town we are using as a model is itself an ancient and walled citadel with a long

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military and political history. The walls enclose the town in a roughly circular shape with gates at the four cardinal points. Only one of the four gates has its tower and one other gate still has remnants of its outer wall, a feature that shows up clearly on the old maps of Ch'u, which may be found in the "Ch'u Chou Tih Chih" or local gazetteer. The town is not oriented about a single point or even about one main street. The approximation of a main street, Central Street, is only one of several important streets. It is, however, the center of one of the two major commercial areas in Ch'u.

Ch'u is a town of 31,000 people, most of this population being concentrated within the walls, with many families living outside but within about one-third of a mile of the walls. These people are concentrated into four centers, one at each gate, the group at East Gate being the largest and most significant. This is the gate which contacts the Tsing-puh Railroad whose first express stop on the way from Pukow is Ch'u Hsien. The street which runs from Central Street to the railroad is called Great Eastern Street and it has two sections, the parts within and without the walls. Along Great Eastern Street are numerous grain shops, large stores, schools, restaurants, in short, all of the services that may be found on Central Street save the government banks, which prefer to locate themselves behind the massive walls. The importance of Great Eastern Street is enhanced by the proximity to the Ch'u or Sandy River, a small stream up which, six months or more of the year, small boats come with goods. The East Gate Outside is also the site of the city's one mechanized industry, a wheat flour mill which operates by steam engine. It should be said that there are no notable conflicts between the East Gate Outside and the town proper. To a large extent, the important merchants of the town proper have establishments also at East Gate; certainly the Chamber of Commerce and the Guilds crosscut the geographical difference.

Not far from Central street are two daily produce markets. East Gate Outside has one large and one small market and South and West Gates have small markets. On south Central Street, there is another produce market, making the total three large and four small daily markets for the town. Each day, starting at about seven o'clock in the morning, the gardeners, fishermen, and small merchants assemble with the items they have for sale. The markets are not the only places at which food may be bought. Indeed, the daily produce markets include sellers of grain only at such times when great price rises place the grains outside the reach of groups normally used to consume them, at which time they must be purchased in minimum quantities. On the way to market many vendors cry their wares, hoping in this way to sell as much as they can as early as possible. Most of the people of the market leave as soon as they have made their purchases or sold their goods. The markets in Ch'u Hsien are not areas of great social contact. For the most part social activities here are confined to the process of exchange. We should modify this in part, however, since there is some, though not extensive, social contact among the various merchants and peddlers in the market. Particular places are associated with certain individuals and there is some tendency for certain products to occupy a definite area. There are many hawkers who prefer to make the bulk of their sales outside the market areas in order to avoid too keen competition of price and quality. The factors that draw a seller to the market are the furnishing of a point of concentration of customers and, much less important, the presence of pleasant social contacts in the periods between sales. For the buyer, the market is an area where he may see the condition of the market and enjoy lower prices through direct competition. The market is also a feature of social control over food retailing, a reflection, on a smaller scale, of licensing restrictions on larger merchants. This type of factor was most apparent during the periods when the Nationalist Government tried to counteract inflation

by enforcing price controls. During one such drive, the local county government was given the responsibility of enforcing the price ceilings, and to accomplish this, the local police were instructed to herd the peddlers into the market areas. Since the markets are simply transient collections of sellers at certain points, the government felt that control would be more easily enforced if the market, particularly the largest market, had a more formal layout. Steps were taken to make a permanent market area out of some vacant land lying between the market street and the Temple of Confucius, land belonging to the hsien. The police were to enforce the move into this area by confiscating the scales of peddlers found making sales outside of this area or other market sectors. The program was carried out after a fashion, but the reaction of the gardeners was almost unanimous. With the exception of the fishermen, who are a depressed income group and require daily sales to insure their subsistence, the market was almost empty of items for sale. When the gardeners' guild was queried, the reply was that the produce was as yet unripe and therefore unfit for sale. The situation became quite desperate when the action of the gardeners was paralleled by similar refusal to trade by the merchants. The situation was partially resolved with the formation of a black market in commodities, but the cashless middle income group suffered badly.

The separate groups resulting from the extended division of labor in Ch'u are numerous. The most significant groupings include merchants, who range from the great 'laobann,' controlling several shops and with influence in different kinds of businesses, to the 'hsiao paw,' the small sidewalk merchant whose entire stock may not be worth more than two or three U. S. dollars. There are also domestic servants, a large group made of individuals of both sexes, who hire out by the season and who, for the most part, are recruited from farms or from poor laboring families with which the employer has some direct or indirect contact. The artisans are quite numerous and include blacksmiths, silversmiths, weavers, basket-makers, bean-curd makers, tailors, and a host of others. The services are conspicuous, probably most important being the men engaged in transportation, the mode being wheelbarrow, back, ricksha or cart. There is also a large category of unskilled, unallied labor. These males furnish a reserve for agricultural and horticultural work in season as well as daily labor on transitory jobs. Such men may, for example, be employed to pull up the weight on a pile driver or to carry bricks and tile in the construction of a building. Lastly, there is the major group of gardeners.

The absentee landlords in Ch'u hardly deserve to be categorized separately. Despite the legitimate existence of such a specialization, the number of people who derive no income and fill no function other than that of landlord is small. Still smaller is the number of families whose income or function is circumscribed by the ownership of land, since, of the small number of landlords who are completely occupied in this work, the greatest part is engaged on behalf of a family or some social group, the other adult members of which are occupied in other activities. These activities are largely professional or commercial, with official position high on the list of professions. The corollary of this situation, that the political bureaucracy is largely made up of members of landlord families, has had great effect on the history of China and its implications in the social organization of the town and particularly of the county seat are profound. The correlation of office and land ownership is highest in the upper brackets of government service. On the hsien level it includes magistrates, secretaries, bureau (k'ou) heads, and the leaders of county districts. The correlation falls sharply with lower clerks, heads of population units (bao and chia), and vanishes before the level of policemen, servant, or attendant is reached.

There is a tendency for the specialized occupational groups to polarize in two

directions independent of the job specialty, this polarization being roughly along the lines of income, more particularly, along lines which combine in a subtle way, income, relation to the system of production, and the historical social position of the individual. Here we meet again the fact of the horizontal nature of absentee landowning which includes the specialties of higher official, prosperous merchant, and prosperous artisan. In the last two specialties, the individual ceases direct work at the specialization becoming, at first, managerial and later even removed from the enterprise. Furthermore, the leadership of the various guilds, the formal structures based on the division of labor, is always vested in the 'gentlemen' of the town, a role that is the very essence of absentee landholding. The leadership of the occupational specializations is thus always vested in a class rather than in the specialties themselves.

The lower elements within a trade also converge outside of their specialties, forming a reciprocation of the upper class phenomenon. These convergences, however, are subject to the scrutiny and censorship of the upper class and there the process is completely unilateral and reciprocation ends. The groups of lower class origin, then, are controlled and patterned by the upper class, if they persist they operate outside the law and must do so in secrecy. An example from Ch'u: as a reaction to the steady increase in rents, there was a local movement among the petty bureaucrats, teachers, and small merchants to form a tenants' union. The association was formed and it petitioned strongly, addressing itself to the public to gain members but appealing to the magistrate for corrective measures. The magistrate advised the union to disband and present petitions individually to the respective landlords. The advice was quickly followed by an order, and, fearing punitive action, the association dissolved.

It is incorrect to think of the county seat or town as other than an integral part of the county, but it is also an error to hold that towns are merely large villages. The basic wealth of Ch'u is in the production of the peasants who constitute a majority of the population of the county. To this agricultural production may be added the labor of artisans who fashion usable commodities from raw materials. The bulk of the town population, however, relies on the exploitation of these elements for its success. For example, the two most immediate drains on the incomes of tenant farmers are rents owed to the landlords and interest owed to usurers, as well as taxes and assessments owed the government. In Ch'u there are two systems for assessing rent. There is a flat and standard amount paid semi-annually, so many 'tan' of rice and so many of wheat, or a percentage arrangement, 40 per cent of the staple crops in season being the usual figure in the area. Thus, at the outset, the peasant parts with the major part of the return from the land he has cultivated, giving the greatest part to his landlord. The merchant, dealing in most cases with landlords of farmers is also dependent on the agricultural production of the hsien though the forces which condition the farmers' lives are mediated in his.

The case for the independence and uniqueness of the town as a social phenomenon depends on a recognition and analysis of the nature of the bureaucracy of government, the structure and importance of military units which are associated with the towns, the concentration of capital in a restricted area, and the concomitant presence of a class of wealthy families and individuals. These factors which are in part inevitably associated with the increase in the size of the community are, nonetheless, discrete and unique phenomena which do not appear on lower organizational levels and which carry in their wake altered conditions which reshape the character of succeeding developments.

Guild phenomena are so negligible in village organization in China that no monograph contains any discussion of them. It is only on the town level, where there is

a concentration of specialists that the guild fills a needed role. The farmers' guild, the one such organization that is extended to rural villages in Ch'u, is not the spontaneous creation of farmers but is a calculated structure imposed from without, whose officers are semi-agents of the state.

Another example of the uniqueness of the town as a social form may be found in the institution of apprenticeship, a development which, in China, is largely independent of the guilds. In the villages, learning is by the imitation and observation of parents whether they are engaged in agriculture or in subsidiary handicrafts.* In the town, a whole new arrangement is found whereby young males are instructed in the techniques of some handicraft or commercial specialty, a relationship which includes a new social relationship that has no proper counterpart in the village.

If a town is related to its agricultural hinterland, it is also vitally connected to other towns and cities and through them with more remote entrepôts and the world community. Some of these connections are clearly revealed in a consideration of the method by which currency enters the town economy, an analysis that points up, once again, the ties of town to country. Beginning with the production of grain, we have seen that a large portion is immediately earmarked for the landlord, an individual who frequently, and in Ch'u Hsien generally, lives in town. The landlord, after he has separated his rents into amounts he will have to pay out as taxes and the part he expects his family to consume, will sell his surplus in order to have money to meet other expenses such as other items of diet, education, clothing, and perhaps rent on his own house. The last, however, is generally paid in rice if the tenant is known to be a landlord.

The grain that is sold by the landlord will go to a local grain shop or to an outport grain store; in either case the rice is destined for the outside. The payment for the exported rice is always made in currency, just as commodities which are purchases from the outside are bought with cash and not bartered for.

Another way in which currency enters Ch'u is in payment of the services of government employees and officials, categories which range from the Magistrate to the railroad laborer. In Ch'u it is clear that the income the town derives from the government is far short of the amount it sends out of the community in taxes. Another factor is that, while the greatest part of the tax payment is in grain, the bulk of salary payments is made in currency.

Money as a commodity leaves Ch'u as well as entering it. A certain amount is drained off institutionally in the form of taxes, the merchants paying their taxes in currency as opposed to landlords who pay in grain. Most of the outgoing cash, however, is expended by merchants who buy consumer goods which are largely the product of Shanghai, Wusih, or the manufacturing cities of foreign countries. The flow of goods imported from the outside should not be underrated, since it is through such medium that much enculturation and culture change is proceeding. The store system in Ch'u has special shops carrying outport items. One type of store, the 'yang-dean' sells items associated with the 洋店 western countries, such as matches ('yang-huo') and kerosene ('yang-yu'). Other shops, called 'kuang huo dean,' sell items that originate in the two Kwang provinces of the Southeast.

We have treated very briefly some aspects of the nature of town phenomena in China, giving special attention to the relationships between the town and the countryside and the town and the larger cities. The examples have been based on data collected in Ch'u Hsien. Generalization from facts gathered in one place is a procedure fraught with danger. Sophisticated Chinese informants warned continually during the study in China that the information did not apply to the country as a whole. Yet, there

* This does not refer to literary training, which, in the village as in the town, is delegated to a specialist.

are many factors which we have touched upon that appear throughout China, and the regularity is more pronounced in the more restricted area of the Yangtze Plain.

It has been shown that a town or county seat, even one with so many outgoing relationships as Ch'u, is organically and functionally tied to the agricultural hinterland. The distinctiveness of the town as a unit of organization has been outlined and the way paved for a later and more important comparison and contrast of county seat and town in some future paper. Lastly, it has been indicated that the town is economically poised between the agricultural hinterland and the large cities and entrepôts which are contacted by railroad, stream, or motor road. Though the present paper has been most concerned with tracing certain economic relationships, all three of the points made above can be extended with materials drawn from the realms of religion, political structure, and social organization.

THE NEGRO KINGDOMS OF THE SUDAN

By JOSEPH GREENBERG*

Monarchical patterns are widespread in Negro Africa and have been reported from peoples as distant from each other as the Shilluk of the Upper Nile Valley, the Zulus of South Africa and the Wolofs of Senegal on the Atlantic Coast. Among African kingdoms, those of the Sudan, particularly in its western portion, have been conspicuous for their size, in which they are without rival in Negro Africa. Their early date of historical attestation is only surpassed by Ethiopia and by the kingdoms of the Nile Valley known from Egyptian records. Moreover, the cultural contributions of these Sudanese kingdoms, under the aegis of Islam, are unique in African history. What follows is a brief attempt to consider some of the factors operative in the rise of these empires and to evaluate those theories, found frequently in the literature, which assign a predominant part in their foundation and expansion to Caucasian influences of one kind or another.

The Sudan is the term applied to that vast portion of the African continent which stretches between the Sahara Desert on the North and the tropical rain forests of the Guinea Coast and the Belgian Congo on the south. In keeping with its transitional nature, it is predominantly steppe in its northern portions and savannah towards the south. Rainfall is generally adequate and both agricultural and pastoral populations are found. A conspicuous trait of the area is the relative ease of west-east movement over its open terrain, a facility intensified by the use of the horse as a riding animal, which is at least as old as the introduction of Islam in this region and perhaps older. At the exit of the last century, Rabeh, an adventurer who had been a lieutenant of Zubeir Pasha, active in a rebellion in the Anglo-Egyptian Sudan, fled across the entire eastern and central Sudan and carved out an empire for himself in the shores of Lake Chad. What has occurred so recently in the full light of history may have happened many times in the past also. Certainly, in this ease of communication in the open lands of the Sudan, we have an encouraging factor for the formation of large territorial units.

The great importance of the Sudan in the commercial history of Africa is its position as an entrepôt for goods crossing the Sahara, and for their exchange with the products of the Sudan itself and of the frost area farther south. The Sudan first enters written history, in this guise, with the activities of Mohammedan merchants from the cities of North Africa. Whether this trade first began after Islam had made its conquest of North Africa in the seventh

* Department of Anthropology, Columbia University, New York, N. Y. This paper, illustrated with lantern slides, was presented at the meeting of the Section on November 22, 1948, and has been submitted for publication at this time.

century, or whether it existed even earlier, has been the subject of some speculation. The Romans, to whom is usually assigned the introduction of the camel into North Africa, without which this trade would have been seriously handicapped, if possible at all, are not likely to have bothered to assure themselves of the control of the oases of the Fezzan in southwestern Libya, had not some trade existed. There is no evidence concerning the Carthaginians before them, though some have thought that Carthage maintained such trans-Saharan routes.

It is clear, at any rate, that the large size of the Negro empires of the western Sudan, their stability over centuries, and the security of travel which they provided, were powerful factors in the development of this trade, while the prosperity which it engendered was, in turn, the *raison-d'etre* for their expansion and wealth. The mere need for such a route is, however, not adequate as an over-all explanation of the existences of these kingdoms. In the seventeenth century, the old organization of the Niger areas in the western Sudan collapsed under the impact of the Moroccan conquest and was never re-established, in spite of the continued operation of the geographical and economic factors which tended to favor this portion of the Sudan. It was the shortness of the route from Morocco, the great bend of the Niger in western Sudan, which led to its early prominence. Islam spread into the interior of Africa along this western path of penetration, trade and religious proselytization going hand-in-hand. The eastern route via the Nile Valley was far less prominent, not only because of its greater length, but because of the persistence of Christian kingdoms in Nubia, which throughout the Middle Ages blocked the southward expansion of Islamic trade and religious conversions.

Our knowledge of the great empires of the western Sudan rests first upon accounts furnished by Arab travelers and by geographers who utilized the reports of Islamic merchants who traded in these regions. Arab materials commence with the tenth century and continue through the Middle Ages. They are sparse in ethnographic detail, but they at least furnish the main outlines of political history. A second source is the Negroes themselves, who borrowed writing and the exercise of historiography, along with other branches of literature, from Islam. The records range from mere lists of kings, with the length of their reigns, to such lively and detailed accounts as the *Tarikh-es-Sudan* of *es-Sa'di*, a native of Timbuctoo. They are an invaluable supplement to the information furnished by Modern European explorers and ethnographers, beginning with the exploration of Mungo Park at the end of the eighteenth century.

The first large kingdom which these sources disclose is that of Ghana, whose existence is attested as early as the tenth century by Ibn-Haukal and is described by El-Bekri, in the eleventh century. The exact location of Ghana is disputed, but it is generally agreed that it was west and north of the great bend in the Niger River, so that it stood as a kind of outpost in the desert for the transmission to the Sudan of goods from the south Moroccan city of Sijilmassa. The rulers of Ghana were pagan throughout its history, although Moslems were welcomed as traders and held important official posts. The capital was divided into two distinct parts, a Moslem city and a pagan city. From El-Bekri's account, it is clear that Islam had spread to the ruling class of other kingdoms of the western Sudan as far west as the Senegal Basin, and eastward to the region of Kukia or Kaokao on the lower Niger, the center of the later Songhoi empire. Ghana became engaged in a struggle with the Almoravids in the eleventh century. These Almoravids were a Berber group from north of the Senegal who, moved by the familiar combination of religious reforming zeal and desire for plunder, finally advanced into Spain, for a time controlling a vast empire, stretching from the Sudan almost to the Pyrenees. They captured Ghana, which subsequently lost most of its

commercial as well as political importance although it was not abandoned until the Fourteenth century.

With the decline of Ghana, empire and trade both moved to the east and the hegemony which it had enjoyed passed to the Mandingo empire of Mali. Its racially Negroid rulers spoke a Mandingo dialect, affiliated with the western Sudanese linguistic stock. Its capital, whose exact location is disputed, was certainly somewhere on the Niger, southwest of the great bend. The great commercial center, however, was now Timbuctoo, which, located on the Niger bend, was beginning to establish the reputation for learning and commercial prosperity that made it eventually a name to be conjured with in Europe. The height of its prosperity was attained in the fourteenth century, to which period belongs the celebrated pilgrimage of Mansa Musa to Mecca, recorded by contemporary Arab writers, and the visit of the great Moslem traveler, Ibn Batutah, to Timbuctoo and to the Mandingo capital.

The Mandingo empire, in its turn, entered a period of decline and its position of leadership fell to the Songhoi, formerly a vassal state. In 1468, the Songhoi ruler, Sonni Ali, entered Timbuctoo and under his successor, Askia-El-Hajj, the Songhoi empire became the largest in the history of Negro Africa, extending from the Atlantic almost to Lake Chad and controlling the important oases of the western Sahara. Timbuctoo, also, attained its greatest intellectual importance during the sixteenth century, especially the university associated with Dyingerey Bey, the great Mosque.

In 1590, a trans-Saharan expedition, launched by the Sultan of Morocco, put an end to the Songhoi empire and with it to the prosperity of Timbuctoo and the preeminent position enjoyed for so long by Negro political units in the Niger area. The Moroccan pashas' power soon declined until it was limited to the city of Timbuctoo. The distant ties with Morocco were dissolved and the activities of the Moroccan soldiery, which deposed and set up pashas at will, prevented the re-establishment of public security and the remarkable safety of travel in these regions noted by such earlier travelers as Ibn Batutah.

As a consequence of this situation, the main lines of trade moved more eastward to the Hausa States, a series of city units bound together by language and traditions of common origin for the ruling class, but without any wider political organization. Native records, if their chronology is to be trusted, put the founding of these States in the eleventh century. Subsequently, the rulers of most of them became at least nominally Moslem. For a time, the western Hausa States were under the rule of the Songhoi Empire, when it was at the zenith of its power under Askia-el-Hajj early in the sixteenth century. The great period of prosperity for the Hausa States dates from the Moroccan conquest of Songhoi, after which the route from the great Hausa cities of Kano and Katsina to Tripoli became the chief avenue of trans-Saharan commerce.

The last important political events in the western Sudan before the advent of the European colonial powers involve the people known variously in the literature as Ful, Fula, Peul, Fulani, and Fellata. An essentially pastoral people, they spread, in historic times, eastward from the Senegal basin in scattered groups, often of considerable size, as far east as Wadai, almost half the distance across the entire African continent. All through these regions they lived as politically impotent, often oppressed groups. Some, at least, became enthusiastic and learned Moslem, while others stayed in the bush as pagans or near-pagans. At the beginning of the nineteenth century under the leadership of Osman-dan-Fodio, and a decade later in the Niger basin under Ahmadu, they proclaimed a holy war against the existing political rulers of the Sudan, whom they called pagans. This crusade was, in general, successful and two great confederations were organized, one, in the east, embracing the Hausa States in a loose confederation with

its capital at Sokoto, and the other at Hamdallahi in the upper basin of the Niger. These political aggregates were in the process of dissolution when the European colonial powers appeared upon the scene. There were other important political units in the Western Sudan in the period under consideration: for example, the cluster of kingdoms with related rulers, the most important of which was Mossi, in the basin of the Volta River south of the Songhoi Empire. The Mossi remain stubbornly resistant to Islam up to the present day and have formed a bulwark against the spread southward to the frost belt of the Guinea Coast. Another notable kingdom is that of Kanem, later Bornu, on the shores of Lake Chad. It has existed with many vicissitudes from the eleventh century, according to native records. Its ruler was converted to Islam in the twelfth century. At times, this kingdom has been of enormous extent and at one time it controlled a portion of the Hausa States. It successfully resisted the Fulani onrush in the nineteenth century, but finally succumbed to Zubeir Pasha's lieutenant, Rabeh, just before the arrival of the French. In the central Sudan, we find the kingdom of Bagirmi, southeast of Lake Chad, Wadai, east of the same lake, and further east still, Darfur, within the boundaries of the Anglo-Egyptian Sudan. All these kingdoms are authenticated by native records from a more recent period than those of the western Sudan, approximately from the sixteenth century onward, but it is probable that at least small material states existed in this area previously. There are local traditions to this effect almost everywhere.

FIGURE 1

There are a number of theories in regard to the great empires of the Sudan whose history we have just traced in general outline, attributing their origin or their main features to Caucasian influence.

One interpretation in regard to these kingdoms is that they owe their existence to the application of Mohammedan political patterns by racially Caucasoid groups. An early and explicit statement is that of Leo Africanus, the well-known sixteenth century scholar and traveller, who attributes the introduction of political organization in the Sudan to the Berber Moslem Almoravids.

In a statement which forcibly reminds us of the pre-Rousseau conception of the primitive we read:

> Our ancient chroniclers of Africa, to wit, Bishri and Meshudi, knew nothing of the land of the Negroes but only the region of Guechet and Cano, for in their times all other places of the land of the Negroes were undiscovered. But in the year of the Hegira 380, by means of a certain Mohumetan which came into Barbary, the residue of the said land was found out, being as then inhabited by great numbers of people which lived a brutish and savage life, without any king, governour, commonwealth or knowledge of husbandry. Clad they were in skins of beasts; neither had they any peculiar wives . . . using hairy skins for beds and each man choosing the leman he had most fancy unto . . . These Negroes were first subject of Joseph, the founder of Morocco, and afterwards under the five nations of Libya.[1*]

Elsewhere, we find less baldly stated the suspicion that these kingdoms are essentially the result of Moslem influence. Thus Delafosse, a standard authority, tells us that there are legitimate doubts concerning the purely Negro character of the great Sudanese kingdoms, by way of contrast with Mossi, which, in his opinion, is purely Negro.[2] The writer in the *Enciclopedia Italiana* mentions "the very interesting hypothesis of the purely Negro origin of these monarchical institutions."[3] P. C. Meyer in his historical survey of the Sudan distinguishes four periods. The first is that of the numerous small heathen kingdoms, which last into the eleventh century, to be followed by the large empires coincidental with the spread of Islam in the Middle Niger.[4] He thus attributes the growth of large states, even if not of political institutions in general in this area, to the influence of Islam.

All these views attributing, in whole or in part, the organization of the large, west Sudanese kingdoms to direct Moslem influences are easily refuted by reference to the known facts about these kingdoms, some of which have already been adduced. On grounds of simple chronological priority, it can be pointed out that each one of them had centuries of stable political organization and wide territorial expansion before the introduction of Islam among the ruling group. For the first of these, Ghana, the evidence is indisputable, inasmuch as its rulers were never converted and it remained pagan throughout its history. So also for Mali, Songhoi, and Bornu the evidence is clear that there was a period of pagan political rule before the introduction of Islam and that the continuity of political institutions was not seriously interrupted by the conversion. The Negro character of Mossi, which was never converted, was, we have seen, emphasized by Delafosse, who is willing to entertain theories of Islamic origin regarding the other states. Indeed, the changes wrought by Islam in the domain of political institutions in this area is very small, and it is striking, that, despite the sparseness of the sources at our disposal, the essentially African nature of Sudanese kingship stands out clearly.

Thus, in the brief account of Ghana by el-Bekri, we find the throwing of dust on the head in greeting the king,[5] the use of royal "interpreters" to repeat everything the king says,[6] the beating of drums to summon a royal audience,[7] the sacrifice of the king's attendants at his death, and sacrifices to the royal ancestors.[8] All of these are clearly African traits and none of them are found in the Islamic kingdoms of North Africa and the Near East. In the Mandingo Empire of Mali, we have likewise the throwing of dust on the head in saluting the king, which struck Ibn Batutah as a characteristic Negro custom,[9] the use of royal "interpreters,"[10] and the important position accorded to the king's chief wife.[11] Similarly in the Songhoi State we find the throwing of dust on the head as a mode of salutation[12] and the office of royal interpreter.[13] We hear on one occasion that a prince regards as a deadly insult the threat on the part of a rival to destroy his drum.[14] This points clearly to the widespread African connection between royal

* By Joseph is meant Yusuf ibn Tashfin, the Almoravid leader. The five nations of Libya are the Berbers. In this division, Leo follows Ibn-Khaldun.

position and the possession of specific drums. In the Songhoi Empire there is present, at least since the time of Askia-el-Hajj, fixed territorial division, each with an associated title and specific privilege and duties, another usual feature of African Monarchical organization absent in the Moslem areas of the Near East. In Bornu, we have, in addition to most of the features already mentioned, the institution of the queen-mother and the queen-sister, each with her own court and officials, which finds its exact parallel in the Uganda kingdom of East Africa.[15]

If the evidence for the essentially Negro character of these kingdoms is so clear, one may well ask why there has been so much hesitation or opposition to this view. Outside of the general tendency to deprecate the Negro which permeates the literature on Africa, there are certain superficial data which lend credibility to a theory of direct Moslem origin. For example, the use of the terms "Sultan" and "Vizier" in the literature gives the impression that we are dealing with Moslem political institutions of the Near Eastern type. Our suspicions should be aroused regarding the validity of such deduction when we read that "in Dar-Fur the use of the term Sultan is connected with the possession of certain drums."[16] Sometimes Sultan, Emir and Vizier have been borrowed into a language of the Sudan from Arabic, most frequently as an alternative to an already existing native word. More frequently, when we find such expressions in secondary sources, they have been drawn from Arab accounts in which Sultan would designate any ruler and Vizier any minister. It no more indicates Moslem origin or influence than the title "king of the Zulus" found in an English account would indicate the British origin of Zulu kingship. Occasionally an Arabic term is borrowed and a new office created, but even in this instance, the institutions remain African. Typical in this respect is the Hausa adoption of the word *waziri* '*vizier*', to designate an additional position of nobility. It is but one of a large number of varied titles without any special pre-eminence. The *waziri*, just as other Hausa noblemen, has his territorial fief and fixed prerogatives. The addition of this office has not produced any significant alteration in the existing political system. The only important Moslem influences on political life of which I am aware is the Fulani establishment of an Amiru l-Mu'minina, 'Commander of the Faithful,' on the model of the caliphate, and the office of the Alcali or judge (from the Arabic *qadi*), who judges in accordance with Moslem law in many Sudanese states.

That it is through Islamic influence that writing was introduced into this region and with it a certain development of intellectual life is indisputable. Impressed with the contributions of Negro intellectuals, particularly those of Timbuctoo and Jenne during the Songhoi period, there is a tendency to attribute all developed institutions, whether intellectual, economic, or political, to Moslem influence. However, as the data already adduced indicate, political organization was Negro in structure before Islam and remained so after its diffusion through the Sudan. It is not legitimate to argue from the undoubted Moslem influence on intellectual life to a Moslem origin for political. So, in early Medieval England, intellectual life was Latin and Christian, but political organization was based on Germanic tradition.

Perhaps more than any other factor, the native African traditions regarding the origin and migration of ruling groups have lent credibility to theories of Moslem origin. These reports have not usually been treated with the scepticism they deserve. In spite of Mohammed's admonition that "the noblest among you is the most pious,"[17] the view has always had some currency in Islam that nobility depends upon nearness of kinship to the Prophet. Hence, the constant attempt in the Islamic world to demonstrate descent from the prophet or at least from a well-known Arab tribe or ruling family. For this reason, the accounts of migrations from Arabia and of Arabian descent found among

practically all Moslem Negro ruling groups are to be discounted. Thus, the founder of the old Sefawa dynasty of Bornu is said to be the celebrated Saif ibn Dhu Yazan, a pre-Islamic ruler of Yemen in southwestern Arabia. The first ruling house of the Songhoi attribute their origin to the same area. The pre-Fulani rulers of the Hausa states trace their descent from Abu-Yazid of Baghdad. Many other examples could be cited of this general tendency. It is amusing to note what short shrift the Arabist, Basset, gives to some of the most cherished views of Africanists on the subject, in his reply to the African student, Carbou's queries regarding the credibility of these accounts.[18] Whenever the specific individuals mentioned in native tradition as ancestors are known from Arabic literary documents, the evidence is clear that they died in the Near East without ever having migrated to Sudan. Were all African native accounts of this nature true, Near Eastern history would be filled with the exodus of eminent men to the Sudan. But not a trace of these movements is authenticated from Arab sources.

The vogue of these stories in the Sudan is so great that they have on occasion been adopted by non-Moslem Negro groups. The royal house of the pagan, Mossi, tell the same story as their Moslem Songhoi neighbors concerning their origin from Za-Alyamen, a migrant from Yemen in Arabia.[19] It is a corollary of this view of migration from Arabia that in at least two instances, Ghana and Songhoi, we hear of an early dynasty of "white kings." Both of these accounts lack all historic authentication and so must be accepted or rejected along with the accounts of migration from Arab with which they are connected.

Since writing did not exist in this area until the introduction of Islam, all our written accounts come from those areas which are already Islamic and "they try to forget . . . their predecessors, because they are ashamed of the pagan period."[20] Our narratives are all written by members of the learned class, who are the most enthusiastic Moslems among the population and anxious to develop the theme of the connection with the land and kin of the Prophet.

An allied but distinct point of view does not specifically stress Moslem influence but attributes the establishment of these kingdoms to Negroes with a large Caucasoid racial admixture which supplies the leaven for cultural achievement. This view is clearly stated by A. H. Keane. "Standing out in marked contrast to all these primitive peoples are the relatively civilized Hamito-Negro or Semito-Negro nations, such as the Mandingo, Songhois, and Fulahs in the west; the Hausas, Kanuri, Baghirmi, and Mabas of the Wadai in the centre; and the Furs and Nubians in the east. . . . From these striking contrasts between the pure Negro and the mixed Negroid peoples, the inference has been drawn that the Negro, left to himself, remains a Negro in every sense of the term, and without miscegenation is incapable of making any advances beyond a low social and intellectual level."[21] Another statement of similar import is that of Meyer that "all these data point to the impulse for the building of States originating from Hamito-Semites who influenced the Negroid elements by mixing with them."[22] Seligman, in his standard work "Races of Africa," describes this process in the following terms: "The mechanism of the origin of Negro-Hamitic peoples will be understood when it is realized that the incoming Hamites were pastoral Caucasians—arriving wave after wave—better armed as well as quicker witted than the dark agricultural Negroes."[23] In the same work, we find the common view that the Bantu languages are the result of a linguistic mixture between a Hamite stratum and a Negroid stratum similar to the Sudanic languages of West Africa, while the Masai and similar pastoral peoples of East Africa are called half-Hamites and stated to reflect an even greater Hamitic linguistic, cultural, and racial preponderance.[24]

It will be observed in these statements that there are both a physical anthropological and a linguistic side to the question. Negroes

are declared to be incapable of founding advanced political structures except through physical mixture with racially Caucasoid groups. Such groups are identified with those Negroids or half-Negroids who speak either Hamitic or Semitic languages, presumably imposed on them by Caucasoid speakers of these languages.

With considerable diffidence, inasmuch as I am not a physical anthropologist, I should like to enter a demurrer to the views which dominate the literature on the physical anthropology of the Negro. We are told that only the "forest Negro of the forest zone of the West African Guinea Coast is the true Negro," since it is only here that the dark-skinned, fuzzy haired, broad-nosed and dolichocephalic type is found in his pure form. All other Negroid types are the result of intermixture with Caucasoid peoples, producing such varieties as the Nilote, the Nilo-Hamite, and the Bantu-speaking groups which dominate the southern part of the continent. It would seem just as logical to assert that only the Nordic show the full Caucasoid characteristics of blond hair, blue eyes and tall stature. We could then attribute classical and oriental civilization to Negroid intermixture and state that the leaders of western European civilization—England, France, and Germany—were only so by virtue of admixture with Negroid types producing the Alpine and Mediterranean types found in large or dominant numbers in England, France and Germany.

Even were we to restrict the term Negro to those of the West African tropical forests, we would find such important Negro political structures as the kingdoms of Dahomey, Ashanti, Benin, and the Yoruba states as evidence of the political abilities of the 'pure Negro.'

The linguistic side of this doctrine is notable chiefly for its reliance on an extension of the term Hamitic, particularly by Meinhof, to many languages beyond the established Hamitic groups of ancient Egyptian, Berber, and Cushite languages of Ethiopia, without adequate and convincing proof of linguistic relationship.[25] A conspicuous case is Fulani. The political successes of this people have perhaps been the point of departure, whether consciously or not, for declaring them to be Hamitic. The linguistic evidence, which would take us too far afield to discuss here, clearly points to Fulani being simply another of the vast group of West-Sudanese languages, all spoken by Negroes. It shows special points of resemblance to the Serer language of Gambia and the Biafada of Portuguese Guinea. Again, the view espoused by Meinhof, that the Bantu languages are a result of intimate fusion of Hamitic with languages of the Sudanese 'Negro,' is in a relation of mutual support to the doctrine that the Bantu physical type is the result of admixture between Negroes and Hamitic speaking Caucasoids. Here again the technical linguistic problems cannot be treated adequately at this point. However, languages do not 'mix' after this fashion, or at least such views are looked upon with extreme suspicion by linguists as unusual and requiring real proof, which has not been offered in this case. The clear fact seems to be that the Bantu languages are related to those of the Western Sudan and that the 'Hamitic' features are illusory.* Likewise, the Masai and other so-called half Hamitic languages are not Hamitic at all, but clearly related to the Nilotic languages of the Shilluk and other tribes of the White Nile as well as the Nuba farther north.**

The independence of language and physical type is a fundamental theoretical achievement of contemporary anthropology and there is no wish to sacrifice it here. It is interesting to see, however, that if we grant the premise that Hamitic and Semitic speech are evidence of Caucasoid racial descent, we can then ask what has been accomplished by peoples of the Sudan who speak indisputable Hamitic and Semitic languages. If infusion of the precious

* This relationship has been noted particularly by D. Westermann without affecting standard doctrine regarding African linguistic relationship. Proof of this extremely obvious connection will soon be published by the writer.

** This was clearly demonstrated by G. W. Murray (1920) in a common-sense demonstration.

Hamitic and Semitic 'blood' has such civilizing effects on the Negro, it should be most manifest in those groups which speak languages of the Semitic and Hamitic group. Actually, the record is most uninspiring. The Tuareg, a Berber Hamitic group, has been present in the Niger bend region since the Middle Ages in large numbers without overcoming surrounding Negroid groups, or founding any political structure of note. The Moroccans, Semitic-speaking Caucasoids, as we saw, conquered the Songhoi Empire, but brought in its stead chaos. The Tunjur Arabs, found throughout the central Sudan, were apparently either pagan or very loosely Moslem Arabs, and yielded political sovereignty to the Mohammedanized Negro people of the Fur in Dar-Fur and the Negro Maba of Wadai. Other Arabs of the Sudan, for example, the Shuwa of Lake Chad, have been politically impotent and contributed scarcely anything to Islamic culture. All this is not meant to prove that Hamitic and Semitic speaking peoples in Africa are incapable of political organization, but to demonstrate the *reductio-ad-absurdum* of the conventional arguments.

Our conclusion, then, is that the great empires of the Sudan were instances of a widespread Negro pattern of political structure and that, stimulated by the trans-Saharan trade and taking advantage of the open terrain afforded by the Sudan, territorial organization on a wide scale and of considerable stability became possible.

Finally, the remarkable degree to which Negro institutions survived under a Moslem exterior may be documented from the example of Dar-Fur.[26] Although under Moslem rulers since approximately 1600, all of the characteristic features of Negro kinship already enumerated were found in a flourishing condition by Nachtigal in the middle of the nineteenth century, although the country was then raided by the Mohammedan governor of the Sudan. There was a keeper of the sacred stool, as in the West African kingdom of Ashanti. The Queen Mother had her own troops and courtiers. An aboriginal compilation of customary law was in alternative use in place of the Moslem Maliki law. The great annual festival was the feast of the drums in the Mohammedan month of Rajab. On this occasion, the slaves devoted to each of the past kings sacrificed animals to the royal souls. For those kings who were Mohammedans, learned men read chapters of the Koran, while, for the ancient pagan line, all proceeded to a pre-Islamic sacred place at Jebel Kora where animals were sacrificed to the pagan royal ancestors.

The skins of the slain animals were employed to cover anew the royal drums for the succeeding year. These are just a few of the observances which convince us that the institution of Darfur resemble those of Ashanti, Dahomey, Uganda, and other Negro kingdoms in a thoroughgoing fashion.

There are indications that the traits of Negro political structure also continued with great persistency under a Christian façade in Ethiopia and under Egyptian influence in ancient Cush and Meroe.*

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* See, for example, the account of king-killing in Diadorus's account of the Nubian Kingdom of Napata (iii, 6). King-killing, a widespread African trait, is unlikely to have been borrowed from Egypt in this instance, since it was already abolished in the early dynastic period, more than two thousand years earlier, and is postulated by Egyptologists from such survivals as the Sed-festival.

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SECTION OF PHYSICS AND CHEMISTRY

APPLICATION OF REACTION RATE PRINCIPLES TO SOME MECHANICAL PROPERTIES OF MATERIALS

By EDWARD SAIBEL*

Introduction. It is well known that, as science progresses, the boundaries between what were formerly isolated and discrete phases of a subject become less and less distinct, and it becomes more difficult and less meaningful to compartmentalize the treatment of problems.

A decade ago such phenomena as creep, viscosity, and fatigue, to mention a few, were considered purely mechanical and were treated as such. That this treatment was inadequate is evident from the fact that the work done on those topics during that period consisted mainly of the accumulation of masses of unrelated and uncoordinated data. Experiments were performed in more or less random fashion, and many variables went uncontrolled because, either no guiding theories had been proposed to develop systematically what those variables were, or the theories proposed were too restricted to account for all the known phenomena.

* Department of Mathematics, Carnegie Institute of Technology, Pittsburgh, Pennsylvania. This paper, illustrated by lantern slides, was presented at the meeting of the Section on May 4, 1948, and has been submitted for publication at this time. There was no meeting of the Section in January, 1949.

Much remains to be done and we have by no means found all the answers. Nevertheless, broad unifying principles have been established, and such subjects as the ones mentioned are now amenable to some kind of systematic treatment. No longer is it necessary to separate chemical from mechanical behavior, with the result that such studies as, for example, the effect of the atmosphere on the fatigue life of metals or glasses may now be treated in a rational manner.

Most mechanical phenomena have not yet been successfully attacked from a molecular point of view; that is, detailed mechanisms have not been set up from which rigorous quantitative analyses may be developed. Noteworthy examples are the fields of plastic flow and fracture. The approach has been more successful from the energy or thermodynamic point of view. The results from the latter treatment have been semi-quantitative in most cases, and adjustable constants have been left in the derivations. But trends have been noted, variables or parameters upon which the system depends have been recognized, and in some cases absolute relationships have been established.

In lieu of the detailed mechanism of a process, it is often possible to set up some model, not too complex, in which units

of perhaps unspecified components or size perform in a certain way. Since, in general, any system may be considered as consisting of a large number of such units, a statistical approach is indicated. Such a method, based on an earlier principle of Arrhenius, has been developed by Eyring and his co-workers.[1] In recent times, other statistical methods and approaches have been developed, as for example, that of Barrer,[2] but for the time being the treatment discussed will be that of Eyring, and this will serve to illustrate the general method and its applications. Even though many valid criticisms have been leveled at the Eyring theory, it still remains the only quantitative one which is workable in most physical situations.

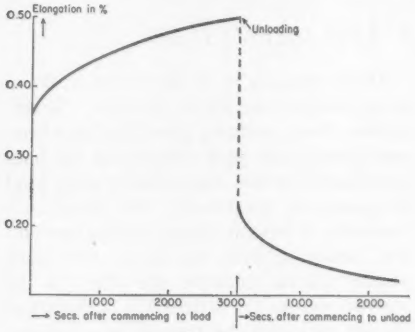

FIGURE 1

General Considerations. Let us consider, for example, what happens to a solid when it is subjected to forces, FIGURE 1.[6] Let us suppose that these forces are applied gradually and that in a macroscopic sense the body is in statical equilibrium, so that no extraneous complexities are introduced into the problem. In some materials and under certain conditions, when the externally impressed forces are small, the deformations may be considered proportional to the forces. When the forces are released, the body returns to its original shape, or at least closely enough to the original shape so that permanent strains are undetectable by the most sensitive of present instruments. We know that, strictly speaking, there must always be permanent changes in a body; because no body is homogeneous. In all cases, there are many sources of stress concentrations within it, and, no matter how small the load, there will be places where the stresses developed through these "stress-raisers" will far exceed the average stress developed. Thus, there will be many places of permanent strain, but so highly localized that for some purposes they may be neglected, particularly in the macroscopic treatment of the body.

As the load is increased, the next stage may be termed the transient stage. Here deformation takes place at a slow and decreasing rate with time. If the loads are removed, the substance still returns, as far as can be determined, to its original shape. But unlike the elastic process, which is extremely rapid, this movement takes place slowly. This effect is called "delayed elasticity" or "elasto-viscous flow." During recovery it is sometimes termed "elastic after-effect."

In the third stage, a steady flow takes place. If the rate of flow is proportional to the stress we have "Newtonian Flow," otherwise, "Non-Newtonian Flow." Such steady flow always leads to permanent deformation. Transient and steady flows take place at measurable and comparatively slow rates. These flows are strongly temperature dependent and are amenable to the general treatment of physical transport processes requiring activation energies.

In the present treatment, the units of flow may be thought of as being situated in an energy field. The equilibrium positions are the potential minima. In general, there will be more of these minimum positions than there are units of flow, and for a unit of flow to move from one of these positions to another, it is necessary to surmount the potential energy barrier. The energy required to do this is called the energy of activation. There is, of course, a certain amount of thermal motion in the system, the amount depending on the

temperature, and there will be some movement over the barriers due to this thermal agitation, but on the whole the distribution of units in space remains constant unless the system is subjected to a potential field. This field may arise from many causes—it may be due to an applied force, or it may be due to a chemical or electrical potential, *etc.* One of the major advantages of the method lies in the fact that it is not necessary to specialize the cause of the disturbance. Another advantage comes about from not having to specify the exact nature of the unit of flow.

Reaction Rate Theory. The process of unit flow is treated in the same manner as a chemical reaction. In its state before flow

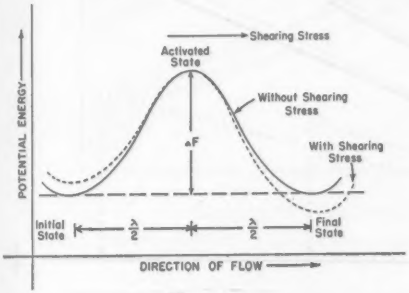

FIGURE 2

it is the reactant, and after the flow has taken place its state is defined as the product of the reaction.

In order to go from one state to the other, it is necessary for the flow unit to attain the energy of activation ΔF^*, FIGURE 2. From statistical mechanical considerations,[1] it may be shown that the specific rate of the reaction in the forward direction is given by

$$n_f = \frac{kT}{h} e^{-(\Delta F^*/RT)} \tag{1}$$

where k is Boltzmann's constant 1.38×10^{-16} *erg deg*$^{-1}$
T is absolute temperature,
h is Planck's constant 6.62×10^{-27} *erg-sec*,
ΔF^* is the free energy of activation or change in free energy in going to the activated state. In other words, it is the energy necessary to get over the potential energy barrier,
and R is the gas constant.

The specific rate in the backward direction is likewise

$$n_b = \frac{kT}{h} e^{-(\Delta F_b/RT)}. \tag{2}$$

In the absence of a potential or force field the net change is zero, since n_f and n_b are just equal. However, if a force is applied so that the work done on a flow unit per jump is w, then

$$n_f = \frac{kT}{h} e^{-(\Delta F^*/RT)} e^{w/kT} \tag{3}$$

and

$$n_b = \frac{kT}{h} e^{-(\Delta F^*/RT)} e^{-(w/kT)}. \tag{4}$$

The net result, n, is now

$$n = n_f - n_b = \frac{kT}{h} e^{-(\Delta F^*/RT)} (e^{w/kT} - e^{-(w/kT)}), \tag{5}$$

or using the definition of the hyperbolic sine, $\sinh u = \frac{1}{2}(e^u - e^{-u})$, EQUATION 5 may be written

$$n = \frac{2kT}{h} e^{-(\Delta F^*/RT)} \sinh \frac{w}{kT}. \tag{6}$$

The net velocity of forward motion is given by the net number of jumps per second multiplied by the distance moved by the flow unit in each jump, λ, thus

$$v_{\text{net}} = \frac{2\lambda kT}{h} e^{-(\Delta F^*/RT)} \sinh \frac{w}{kT}. \tag{7}$$

Several important cases arise which we shall treat separately.

Case I $w \ll kT$

Physically this means that the work done is small in comparison with the thermal energy. Since for small values of u, $\sinh u \simeq u$, we may write

$$v = \frac{2\lambda kT}{h} e^{-(\Delta F^*/RT)} \cdot \frac{w}{kT} = \frac{2\lambda w}{h} e^{-(\Delta F^*/RT)}. \quad (8)$$

The work done, w, may be expressed in the form $\frac{f\lambda_2\lambda_3\lambda}{2}$ where f is the shearing stress on an element of area $\lambda_2\lambda_3$ and acting through the distance $\frac{\lambda}{2}$ from the initial state to the top of the energy hill. Thus

$$v = \frac{f\lambda_2\lambda_3\lambda^2}{h} e^{-(\Delta F^*/RT)}. \quad (9)$$

However, by definition

$$\text{viscosity} = \frac{f}{(\text{velocity})/\lambda} = \frac{h\lambda}{\lambda_2\lambda_3\lambda^2} e^{\Delta F^*/RT} \quad (10)$$

λ being the distance between layers.

The three λ's are approximately equal, their product is approximately the volume of the flow unit, so we may write,

$$(\text{vicosity})\ \eta = \frac{Nh}{V} e^{\Delta F^*/RT} \quad (11)$$

where V is the volume of a flow unit, and N is Avegadro's number. Taking the logarithm of this equation it is apparent that, if the relation is true, log viscosity plotted against $\frac{1}{T}$ should give a straight line. This is shown in FIGURE 3, taken from Houwink[6].

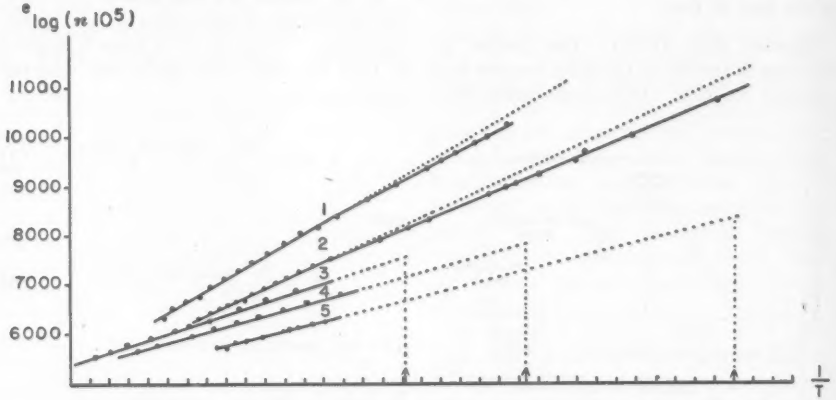

FIGURE 3. Curve (1) n-prophyl-alcohol; (2) ethyl-alcohol; (3) o-xylene; (4) n-octane; (5) methyl-acetate.

This kind of flow, in which velocity is proportional to the shear force, is termed "Newtonian Flow."

Since

$$\Delta F^* = \Delta H^* - T\Delta S^* + p\Delta V^* \quad (12)$$

the dependence of viscosity on pressure may be brought out when the equation for the viscosity is written in the form

$$\eta = \frac{Nh}{V} e^{-(\Delta S/R)} e^{(\Delta H/RT)} e^{p(\Delta/RT)} \quad (13)$$

where ΔH^* is the heat of activation
ΔS^* is the entropy of activation
ΔV^* is the volume change during activation
and p is the pressure

The volume change during activation may be interpreted as the volume of the hole which must be provided for a molecule or unit to flow. For a number of simple liquids this is about $\frac{1}{4}$th or $\frac{1}{8}$th of the volume of a molecule, while for molten metals it is about $\frac{1}{4}$th of the volume of a metal ion. The effect of pressure is shown in FIGURE 4, taken from Eyring and Powell.[4]

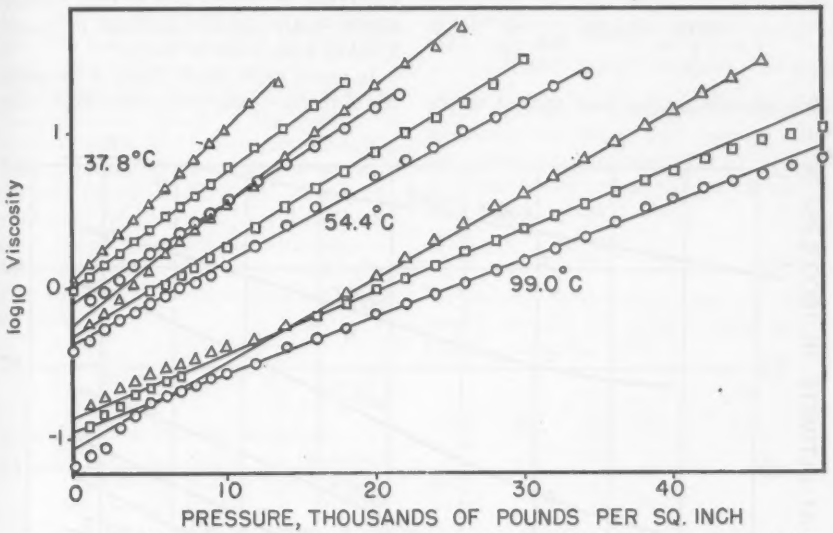

FIGURE 4. Effect of pressure on the viscosity of lubricating oils. (Circles correspond to Pennsylvania oil, squares to Oklahoma oil, and triangles to California oil.)

Case II $w \gg kT$

When the work done by the field is extremely large in comparison with the thermal energy, the free energy necessary to reach the top of the energy hill must also be large compared to kT. The basic equation may be written

$$w = \frac{\Delta F^*}{N} - kT \ln \frac{\lambda kT}{vh}. \qquad (14)$$

This is obtained by using $\sinh u = \frac{1}{2}e^u$ for large u. When the second term may be neglected in comparison with the first, all the work necessary to reach the top of the potential hill must be done by the applied force. This amounts to $\frac{\Delta F^*}{N}$ per molecule. Note that this is the value approached as T approaches absolute zero. In this state no thermal energy would be present and no motion would take place until the critical stress $f = \frac{\Delta F^*}{V}$ was reached. A general relationship between yield stress and temperature may be deduced.[5]

$$f_y = A - BT \qquad (15)$$

where B is approximately independent of T. This may be contrasted with the same type of relationship developed by Becker and Orowan.[6]

$$f_y = A - B\sqrt{T}. \qquad (16)$$

Unfortunately, sufficient data are not available for a critical appraisal of the two expressions. This type of equation has been applied to the sliding of one body on another under dry friction. Here, too, a yield point phenomena is observed: that is, up to a certain critical load no motion takes place;

beyond that critical value, the system moves.[7]

Case III Here w and kT are of the same order of magnitude, and the general expression for the velocity is given by

$$v = \frac{2kT\lambda}{h} e^{-(\Delta F^*/RT)} \sinh \frac{w}{kT}. \quad (17)$$

This relationship has been applied to the problem of creep in metals,[8] although in many cases it is sufficiently accurate to use the formula of Case II

$$v = \frac{kT\lambda}{h} e^{-(\Delta F^*/RT)} e^{w/kT} \quad (18)$$

Shear rate =

$$\frac{v}{\lambda_1} = \frac{kT\lambda}{h\lambda_1} e^{\Delta F^*/RT} e^{f\lambda_2\lambda_3\lambda/2kT} \quad (19)$$

where λ is the average distance between the layers, which slide relative to each other. This leads to

$$\log (\text{shear rate}) = A + Bf. \quad (20)$$

EQUATION 20 may be seen to hold approximately under certain conditions in FIGURE 5, taken from work of Nadai.[9]

In recent years, applications of the methods of reaction-rate theory have been made to various other problems. In what follows we shall limit ourselves to a few examples in which applications to mechanical problems and the question of the interpretation of the quantities entering into the expressions are involved.

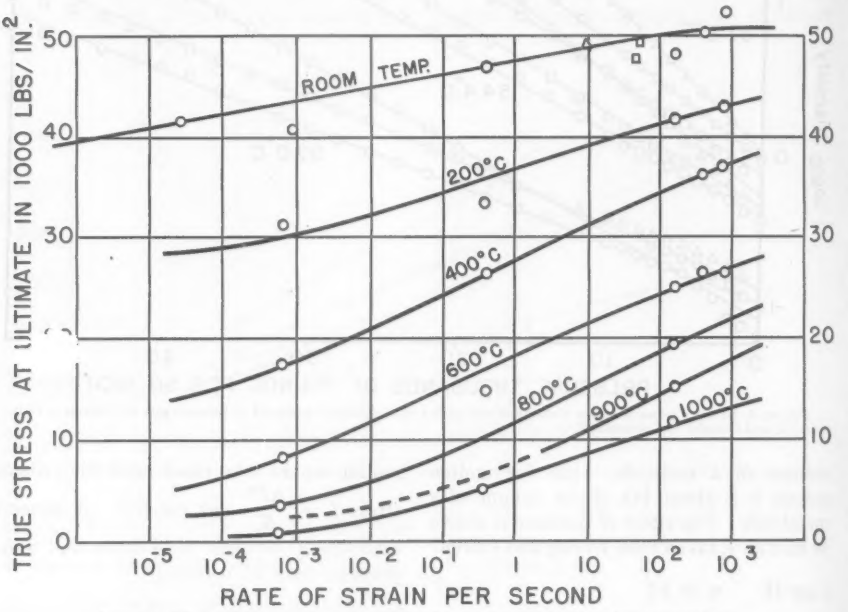

FIGURE 5. Effect of strain rate on true stress at ultimate of pure copper at various temperatures.

Speed of Propagation of Fracture Cracks. The phenomenon of the so-called "brittle fracture" of metals, in particular of steel, has been the subject of much attention in recent years, principally because of its connection with the catastrophic failure of

welded cargo vessels.[18] One of the characteristics of this type of rupture is the extreme speed with which the crack is propagated along the plate. We have seen that the velocity of a reaction may be expressed in the form given by EQUATION 18. This equation will be used to determine the rate of propagation of a fracture crack in the following manner:

Sometime ago, the author[10] developed a thermodynamic theory of the fracture of metals in which fracture was related to the melting phenomenon, use being made of the hole theory of the liquid state. The abolition of cohesive strength was attributed to the formation of the hole structure. It was shown that the fracture took place when the critical energy density u_c reached the value

$$u_c = \left(L \frac{\Delta V}{V_s} + p \right) \qquad (21)$$

where L is the latent heat of melting,
ΔV is the change in molecular volume on passing from the solid to the liquid state,
V_s is the molecular volume of the solid at the melting point,
and p is the hydrostatic component of the force system acting at the point of formation of a hole. If this component is compression, p is to be taken as positive.

The speed of fracture will be determined from the rate at which the holes are formed. The metal just before rupture is considered the reactant, and the fracture crack which is formed is taken to be the product of the reaction, so that, in the present interpretation, the substance is in the activated state when the holes are formed. Thus, w is defined as the energy necessary to form one hole. These holes will be thought of as being spherical and of an average uniform size. The mechanism of crack propagation will be assumed to take place through the continuous formation of holes. Each time a hole is formed, the distance advanced by the crack will be equal to the diameter of the hole and will correspond to λ in the fundamental equation. The critical condition for the energy density will be assumed satisfied so that crack propagation will continue. The evaluation of the terms entering in the equation for the velocity is as follows: we may express the free energy of activation in the form

$$\Delta F^* = \Delta H^* - T\Delta S^* \qquad (22)$$

if the hydrostatic component of stress be neglected. In order that fracture take place the energy corresponding to the heat of activation must equal the critical energy of EQUATION,[21] thus

$$\Delta H^* = u_c. \qquad (23)$$

We assume, furthermore, that the work done in forming the holes is equal to the heat of activation. Now

$$\frac{w}{kT} = \frac{Nw}{RT} = \frac{N}{n_h} \cdot \frac{n_h w}{RT} = n \frac{\Delta H^*}{RT} \qquad (24)$$

where $$n = \frac{N}{n_h}.$$

We may now write the equation for the velocity of propagation in the form

$$v = \frac{2\lambda kT}{h} e^{(\Delta S^*/R)} e^{-(\Delta H/RT)} \sinh \frac{n\Delta H^*}{RT}. \qquad (25)$$

The entropy change of activation for the process is calculated by considering the liquid to be a random mixing of molecules and holes[11]. This leads to the expression

$$\Delta S^* = Nk[(1+\gamma)\ln(1+\gamma) - \gamma \ln \gamma] \qquad (26)$$

where $$\gamma = \frac{1}{n} = \frac{n_h}{N}.$$

Also $\Delta V = n_h \cdot \frac{1}{q} \frac{V_s}{N}$, if it be assumed that the whole volume change on melting be due to the formation of holes and that the volume of a hole V_h be defined as $\frac{1}{q}$ times the effective volume of a molecule $\frac{V_s}{N}$.

Thus $\frac{1}{n} = q\frac{\Delta V}{V_s} = \gamma$, and from a knowledge of $\frac{V}{V_s}$ and of γ, q may be found. The value of n may be taken to be 2^1, in accordance with known entropy values, as well as other evidence. Furthermore, for Fe, $\frac{\Delta V}{V_s} = 0.045$.[12] From this it follows that q is approximately 11. Using this value and $V_h = \frac{1}{q}\frac{V_s}{N} = \frac{4}{3}\pi\frac{d_o^3}{8}$, we find that the average diameter of a hole, $d_o = 1.28 \times 10^{-8}$ cm. The heat of activation $\Delta H^* = L\frac{\Delta V}{V}$ is equal to 160 cal/mol and $\Delta S^* =$ 0.95 R. From these numerical data the speed of propagation v becomes

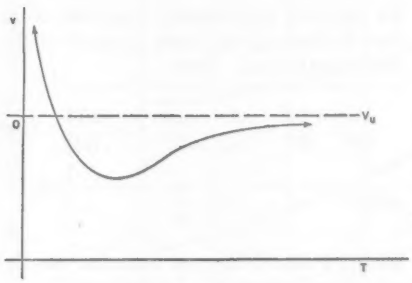

FIGURE 6

$$v = 542Te^{-80/T}\sinh\frac{160}{T}\text{ in/sec.} \quad (27)$$

At room temperature, $T = 300°$ K, and $v = 69{,}500$ in/sec. Hudson and Greenfield[13] find an average experimental value of 40,400 in/sec.

It is interesting to note that no adjustable constants enter in this calculation, although it may appear that the value of n may be varied. This value is determined, however, by the known value of the entropy of melting. The fact that the calculation gives a somewhat high value may be explained from the assumed straight line motion of the crack. Actually, although not random in character, it zigzags through the metal, and the net macroscopic speed is slower than the calculated speed. Furthermore, no account was taken of the hydrostatic component, which may well effect the results.

If the speed of fracture be written in the form

$$v = ATe^{-(\Delta H^*/RT)}\sinh\frac{n\Delta H^*}{RT} \quad (28)$$

where A is independent of temperature, two things become apparent, FIGURE 6. First, there exists a minimum speed at a certain temperature. This is found to be when

$$\tanh nx = \frac{nx}{1+x} \quad (29)$$

where $$x = \frac{\Delta H^*}{RT}.$$

And secondly, as the temperature increases, the speed of fracture approaches, asymptotically, a limited value. This limiting speed seems to be the speed of propagation of sound in the liquid at the melting point. For example, using EQUATION 28 and allowing T to become large, we find

$$v_u = \frac{n\Delta H^*}{R}\frac{2k\lambda}{h}e^{\Delta S^*/R} \quad (30)$$

which for iron gives 94,400 in/sec, and for copper 70,200 in/sec. The speeds of sound in these two materials in the liquid state and at the melting point are approximately 100,000 in/sec and 70,000 in/sec, respectively.

Static Fatigue of Glass. Another problem of much interest is that of the strength of glass under a static load. As early as 1899, Grenet observed that a glass specimen which would withstand the application of a load for short periods of time would fail under smaller loads which were applied for longer periods. Since that time, a great deal of experimental work has deen done and tests of duration ranging from 10^{-2} sec to 10^5 sec have been carried out. Many explanations of the phenomenon have been advanced and

many empirical formulae have been shown to fit the data about equally well. Typical graphs of the relationship of load and time to fracture are shown in FIGURES 7 and 8, taken from REFERENCES 14 and 15 respectively, the former being for glass and the latter for rayon used in tire cord. As a matter of fact, there seems to be a wide class of materials to which the same general principles may be applied and for which the general relationship of time to fracture and load holds. In all of these cases, the effect of the surrounding atmosphere is important and may be taken into account in the treatment that follows, FIGURE 9.[16] The effect of the atmosphere is also apparent in FIGURE 7, where the curve has been lowered by both the scratching of the glass and the wetting of the surface.

As is well known, the structure of glass is irregular, like that of a liquid. There is no repeating regularity, although there is some degree of order, in any small neighborhood. The model on which we shall base our calculations is capable of several interpretations. The simplest case, SiO_2 in the amorphous state, has each silicon surrounded by four oxygens and each oxygen by two silicons in a sort of distorted tetrahedral arrangement. One may think of a distribution of primary *Si-O* bond strengths existing in any neighborhood due to missing bonds, cracks, holes, *etc.* Or one may imagine this distribution of strength as due to initial strains of varying amounts in the bonds filling the elemental region, the size of which is as yet not determined.

Parenthetically, it may be pointed out that, since the average strength of the primary bonds is rather large, it has been suggested that it is not these bonds which are broken, but rather the Van der Waals or secondary bonds, which are postulated to act between aggregates or regions of the material.[6] Because these forces are much weaker than the primary forces, some have asserted that it is more reasonable to set up the fracture process in terms of the secondary bonds. Evidence of the existence of these bonds is lacking, however, and as we shall see, it is not necessary to specify in detail the nature of the fracture mechanism for our purposes. It will be sufficient to assume a distribution of bond strengths and to show that out of it a relation between

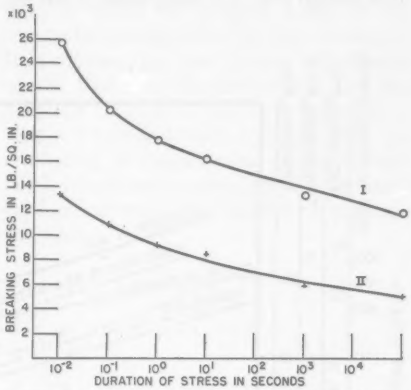

FIGURE 7. I. Disannealed Pyrex, dry; II. Disannealed Pyrex, scratched, wet.

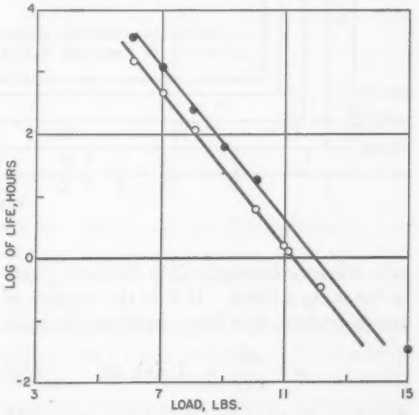

FIGURE 8. Life under dead load as a function of load for cotton tire cord (after Busse et al.).

fracture stress and time develops, which correlates with the experimental evidence and may, in fact, be used to determine the nature of the bond strengths themselves.

In the following treatment we shall consider the glass before fracture as the reactant; and broken bonds, the product of

the reaction. As we have seen before, the rate of the reaction, n, may be expressed

$$n = A \sinh Bf \qquad (31)$$

where f is the force acting on a bond, related to w though $w = \frac{f\lambda}{2}$, λ being some characteristic distance through which the force f acts in breaking a bond. If N is the number of bonds broken, this basic equation becomes

$$n = \frac{dN}{dt} = A \sinh Bf. \qquad (32)$$

The force f acting on a bond may vary with time for several reasons:

a. The load acting on the specimen may be changing.
b. As bonds are broken, the remaining ones have to assume larger loads.
c. The directions of the bond elements may be changing.

We consider the case where the load is applied in a steady manner, as for example, constant tension in the macroscopic sense. As a first approximation assume that

$$f = fo + cN \qquad (33)$$

where c is a constant and fo is the force on a bond when the load is first applied. Then

$$\frac{dN}{dt} = A \sinh B(fo + cN). \qquad (34)$$

Integrating and assuming that the number of bonds which must be broken to bring about fracture is large, we find

$$t_B = \frac{1}{ABc} \log \coth \frac{B}{2}(fo + cNo) \qquad (35)$$

where t_B is the time to fracture
N_B is the number of bonds which must be broken to bring about fracture in the usual sense.

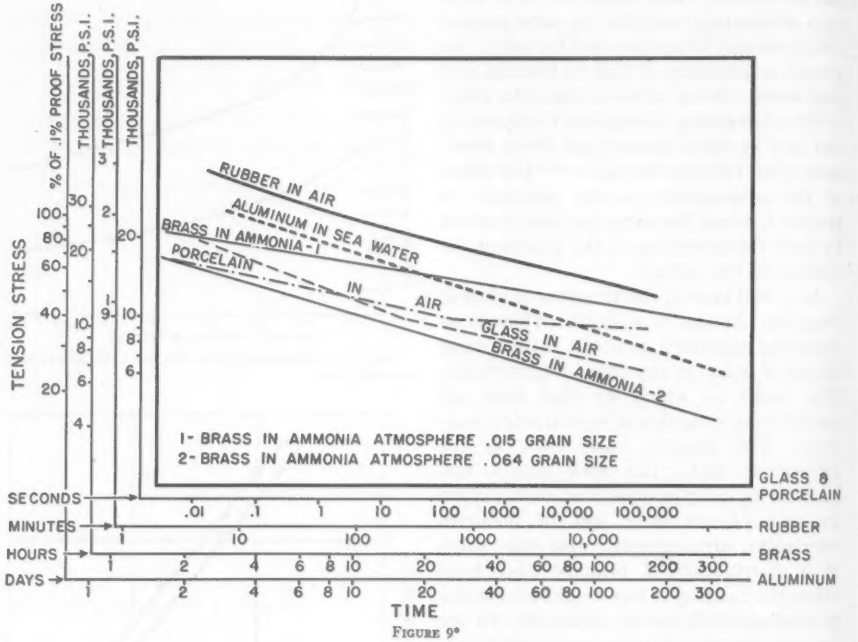

FIGURE 9*

* Sources of materials used: glass and porcelain from Preston-Preston Laboratories; rubber from Sloman-U. S. Rubber; brass from Morris-Bridgeport Brass Co.; aluminum from George & Chalmers—Brit. Iron & Steel Inst.

No is the number of bonds already broken at the start of the test $t = 0$.

This in turn may be inverted to yield

$$B(fo + cNo) = \log \coth \frac{ABc}{2} t_B \quad (36)$$

where

$$A = \frac{2kT}{h} e^{-(\Delta F^*/RT)}$$

and

$$B = \frac{\lambda}{2kT}.$$

If we assume that $No = 0$, EQUATION 36 may be written

$$f = D \log \coth E t_B. \quad (37)$$

D and E are parameters independent of the applied force. The general shape of the curve representing EQUATION 37 is shown in FIGURE 10, where because of the large range in values of t which must be covered, the fracture stress is plotted against the logarithm of time. Notice that over a fair sized range the curve is nearly straight, since for small values of the argument, *coth* $x \approx \frac{1}{x}$. Thus

$$f = D \log \coth Et \approx -D \log Et. \quad (38)$$

On the other hand when the argument of the hyperbolic cotangent is large,

$$\coth x \approx 1 + 2e^{-2x}$$

and $$\log \coth x \approx 2e^{-2x} \quad \text{so that}$$

$$f \approx 2De^{-Et} \text{ for large } t_B. \quad (39)$$

This latter expression invites comparison with the equation of relaxation of tension with time in a material stretched to some value just below the breaking load and held at constant length. It is well known that under these conditions the load P varies with time t in the following manner for some materials

$$P = A e^{-Bt} \quad (40)$$

which is precisely the form developed above. In some respects the two problems are comparable, for if the load is held just below the breaking point one might well imagine that this load behaves with time in the same way as the breaking load does.

No attempt has been made in this treatment to obtain the absolute values of the constants entering into the basic formulae. It is evident that their values will depend on the nature of the atmosphere and the resulting chemical action that takes place. This will manifest itself in general through a lowering of the potential energy barrier and a consequent lowering of the mechanical force necessary for fracture in a specified time.

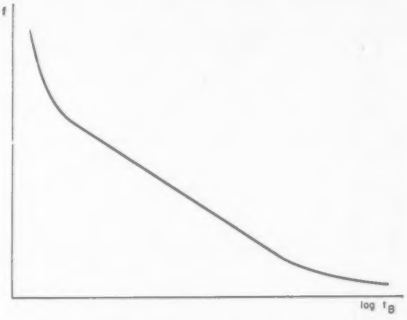

FIGURE 10. $f = D \log \coth Et_B$

The simple picture of a substance consisting of numerous similar units does not always lead to a satisfactory solution of a problem.

An example of this arises in the attempt to account for the variation of the viscosity of glass with temperature. Recall that, from the Eyring point of view, log viscosity vs. $\frac{1}{T}$ should be a straight line. However, as can be seen from FIGURE 11, which is characteristic, such is not the case. The modification as performed by Powell[3] is to assume two molecular species, miscible and in equilibrium with each other. These are designated as a low temperature form (LT) and a high temperature form (HT), and the

composition of the mixture is supposedly given by

$$\frac{(HT)}{(LT)} = \text{Kequ.} = e^{-(\Delta Fo/RT)} \qquad (41)$$

where ΔFo is the free energy change of the reaction. It is also assumed that the viscosity of mixtures is given by

$$\eta = \frac{Nh}{\text{Vave}}\, e^{(\Delta \text{Fave}/RT)} \qquad (42)$$

where $Fave = N_1\Delta F_1 + N_2\Delta F_2 \ldots$; N_1, N_2, ... being the mole fractions of the mixture. This means that the free energy of activation required for the flow process may be expressed as a weighted average. EQUATION 42 may be put in the form

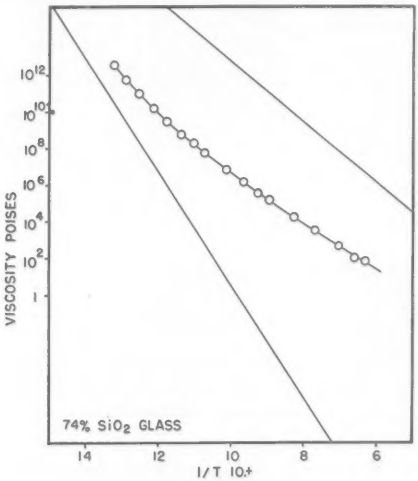

FIGURE 11

$$\log(\text{viscosity}) = N_1 \log(\text{viscosity}_1) + N_2 \log(\text{viscosity}_2) + \ldots \qquad (43)$$

The agreement between theory and experiment for the viscosity of glasses is then found by assuming two straight lines in the $\log \eta$ vs. $\frac{1}{T}$ diagram, so that the combination results in the experimental curve.

This may be compared with the concept of Murgatroyd,[17] who postulates a diphase material in order to account for the time effect in the fracture of glass. He envisages a quasi-viscous material in an elastic matrix. When the glass is stressed, relaxation in the viscous pockets throws more of the load on the elastic portion, and, after a certain length of time, fracture occurs. Of course, it is not necessary to impose a limit in this concept to just two components; any number may be postulated. In fact, some advantage may be gained by assuming an infinite number and by determining the relaxation spectrum by known mathematical methods.

No conclusive physical evidence has been found, however, to indicate a diphase nature in glass, and the previously mentioned methods for treating the viscosity of glasses as a function of the temperature must be regarded as empirical devices in which more constants are introduced to enable one to come closer to the experimental findings.

The method of Barrer, which was mentioned earlier, attempts to account directly for various possible mechanisms and types of units within the body. In this theory it is assumed that (a) the energy of activation is distributed over a zone of degrees of freedom, and (b) cooperation may be needed between rotations of inter-molecular vibrations before the unit act of flow or diffusion can occur. The Maxwell-Boltzmann statistics are applied and various energies of activation and cooperative factors are introduced. It still appears necessary, however, to find these energies of activation and the cooperative factors from experimental data.

Conclusion. The theory of rate processes gives numerical results close to the experimental values in many problems. This is particularly true when one or more of the parameters are treated as adjustable constants and values are assumed which bring about good agreement. When this procedure fails to bring results, more than one species may be postulated and more adjustable constants introduced to be played

around with until agreement with experiment is reached. While useful in the absence of better methods, this procedure is hardly satisfying.

On the other hand, models of systems can be set up and, in the course of interpreting the physical processes taking place, absolute values worked out. The value of the method in such cases would appear to come from having a statistical theory made up in advance, capable of many interpretations and ready to apply.

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THE NEW YORK ACADEMY OF SCIENCES

announces

THE A. CRESSY MORRISON PRIZE CONTEST FOR 1949

The New York Academy of Sciences announces the following prize contest for the coming year:

Two prizes of $200 each, offered by Mr. A. Cressy Morrison, to be known as the A. Cressy Morrison Prizes in Natural Science, will be awarded at the Annual Meeting, December, 1949, for the two most acceptable papers in a field of science covered by the Academy or an Affiliated Society.

CONDITIONS GOVERNING THIS CONTEST

(1) *Eligibility.* Authors and co-authors competing for prizes in this contest shall be members in good standing of The New York Academy of Sciences or one of its Affiliated Societies, but non-members may become eligible by joining one of these organizations before the closing date.

(2) *Date.* Papers are to be submitted on or prior to October 15, 1949, to the Executive Director of The New York Academy of Sciences, at The American Museum of Natural History, Central Park West at 79th Street, New York 24, N. Y.

(3) *Papers.* All papers submitted must embody the results of original research not previously published. The manuscript shall be typewritten, in English, accompanied by all necessary photographs, drawings, diagrams and tables, and shall be ready for publication. Papers must be accompanied by a summary of the data presented and conclusions reached, together with an abstract suitable for press release.

(4) *Awards.* The awards shall be made by the Council of The New York Academy of Sciences. If, in the opinion of the judges, no paper worthy of a prize is offered, the award of a prize or prizes will be omitted for this contest.

(5) *Publication.* The Academy shall have first option on the publication of all papers submitted in competition, unless especially arranged for beforehand with the authors, but such publication is not binding on the Academy.

(6) Wherever and whenever published, the papers awarded the prizes shall be accompanied by the statement: "Awarded an A. Cressy Morrison Prize in Natural Science in 1949 by The New York Academy of Sciences."

Such a statement, in substance, must also accompany any formal publicity initiated by the author regarding the prize paper. If published elsewhere, six copies of each prize paper must be deposited shortly after publication with the office of The New York Academy of Sciences.

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Executive Director

CONFERENCE HELD

SECTION OF BIOLOGY

CONFERENCE ON "THE PLACE OF STATISTICAL METHODS IN BIOLOGICAL AND CHEMICAL EXPERIMENTATION": JANUARY 28 AND 29, 1949

The Section of Biology of the Academy, the Biometric Society, and The New York Metropolitan Chapter of the American Statistical Association held a Conference on "The Place of Statistical Methods in Biological and Chemical Experimentation." Doctor Edwin J. de Beer, The Wellcome Research Laboratories, Tuckahoe, New York, was the Conference Chairman in charge of the meeting.

The program consisted of the following papers:

Friday, January 28

Morning Session. Chairman, Edwin J. de Beer, The Wellcome Research Laboratories, Tuckahoe, New York.

"Introductory Remarks," by the Conference Chairman.

"The Statistical Part of the Scientific Method," by George W. Snedecor, Iowa State College, Ames, Iowa.

"The Function of Designs in Experimentation," by Gertrude Cox, Institute of Statistics, University of North Carolina, Raleigh, North Carolina.

"Some Rapid Approximate Statistical Procedures," by Frank Wilcoxon, American Cyanamid Company, Stamford, Connecticut.

Afternoon Session. Chairman, George W. Snedecor, Iowa State College, Ames, Iowa.

"Statistics in Analytical Chemistry," by W. J. Youden, National Bureau of Standards, Washington, D. C.

"A Large Planned Experiment in Penicillin Production," by K. A. Brownlee, E. R. Squibb & Sons, New Brunswick, N. J.

"Statistics in Nutrition Research," by Robert A. Harte, Arlington Chemical Company, Yonkers, N. Y.

"Some Examples of the Use of Statistics in Pharmacology," by Claude V. Winder, Parke, Davis and Company, Detroit, Michigan.

Saturday, January 29

Morning Session. Chairman, Gertrude Cox, Institute of Statistics, University of North Carolina, Raleigh, North Carolina.

"Design of Biological Assays," by Chester I. Bliss, Connecticut Agricultural Experiment Station, New Haven, Connecticut.

"Statistics in Experimental Immunology," by H. C. Batson, Department of Biologic Products, Army Medical Department Research and Graduate School, Army Medical Center, Washington, D. C.

"Statistics in Microbiological Assay," by Lila F. Knudsen, Food and Drug Administration, Washington, D. C.

"Biologic Assays Based on Quantal Responses," by Lloyd C. Miller, Sterling-Winthrop Research Institute, Rensselaer, N. Y.

"Statistics in Biological Assay—The Graded Response," by Bert J. Vos, Division of Pharmacology, Food and Drug Administration, Washington, D. C.

Afternoon Session. Chairman, Lloyd C. Miller, Sterling-Winthrop Research Institute, Rensselaer, N. Y.

"Statistics in Clinical Research—Some General Principles," by Donald Mainland, Dalhousie University, Halifax, Nova Scotia, Canada.

"Statistics in Clinical Research," by D. D. Reid, London School of Hygiene and Tropical Medicine, London, England.

"What is a Mortality Rate?" by H. M. C. Luykx, New York University, New York, N. Y.

"Statistics and World Population," by Forrest E. Linder, Statistical Office, United Nations, Lake Success, Long Island, N. Y.

NEW MEMBERS

Elected January 27, 1949

LIFE MEMBERSHIP

Atwood, Kimball C., M.D., Genetics. Research Associate in Microbiology, Columbia University, Department of Zoology, New York, N. Y.

Burnett, Verne, A.B., General. Partner, Verne Burnett Associates, New York, N. Y.

Eger, Saul D., M.D., Internal Medicine. Physician to Home Care Department, Montefiore Hospital, New York, N. Y.

Fisher, Joel., B.A., Geology, Glaciology. Treasurer, American Alpine Club, New York, N. Y.

Freedman, Robert H., M.D., Internal Medicine. Externe, Montifiore Hospital, New York, N. Y.

Freid, Jacob R., M.D., Radiology. Attending Radiotherapist, Montfiore Hospital, New York, N. Y.

Kahn, Arthur J., B.A., Biology. Research Assistant, New York University, New York, N. Y.

Kolk, Laura A., Ph.D., Botany, Mycology. Associate Professor, Brooklyn College, Brooklyn, N. Y.

Livingston, Ernest M., Ph.D., Chemistry. Assistant Professor, Brooklyn College, Brooklyn, N. Y.

Masterson, Teresa, Ph.D., Chemistry. Assistant Professor, Brooklyn College, Brooklyn, N. Y.

Maurmeyer, Robert, Ph.D., Chemistry. Assistant Professor, Brooklyn College, Brooklyn, N. Y.

Roth, Chester H., Manufacture of Rayon Yarns. President, Chester H. Roth, Inc., New York, N.Y.

Silberman, David E., M.D., Allergy. Assistant Clinical Professor of Medicine, New York Medical College, New York, N. Y.

SUSTAINING MEMBERSHIP

Chua-Chiaco, Manuel, M.D., Microbiology, Nutrition. Assistant Director, Chinese General Hospital, Manila, Philippines.

Demmerle, Richard L., A.B., Chemistry. Associate Editor, Chemical and Engineering News, New York, N. Y.

Joslin, Doyle, M.D., Biophysics, Physiology. Instructor, Department of Physiology, Cornell Medical College, New York, N. Y.

Lowy, Edward J., Sc.D., Industrial Chemistry. Partner, Kem Laboratories, Bronx, N. Y.

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Sohval, Arthur R., M.D., Internal Medicine. Adjunct Physician, Mt. Sinai Hospital, New York, N. Y.

Solotorovsky, Morris, Ph.D., Bacteriology, Chemotherapy. Research Associate, Merck Institute for Therapeutic Research, Rahway, N. J.

Steiner, Paul, General. Director, Chanticleer Press, New York, N. Y.

Zintel, Harold A., M.D., D.Sc., Surgery. Assistant Professor of Surgery, University of Pennsylvania School of Medicine, Philadelphia, Penna.

ACTIVE MEMBERSHIP

Aborn, Murray, M.A., Psychology. Assistant in Guidance, Teachers College, Columbia University, New York, N. Y.

Almy, Thomas P., M.D., Gastroenterologic Diseases, Cancer. Associate Professor of Neoplastic Diseases, The New York Hospital, New York, N. Y.

Atwood, Sanford S., Ph.D., Cytogenetics, Plant Breeding. Professor, Department of Plant Breeding, Cornell University, Ithaca, N. Y.

Auster, Lionel S., M.D., Cancer Research. Attending Surgeon, Bronx Hospital, New York, N. Y.

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Bass, David E., A.B., Biochemistry, Physiology. Biochemist, Climatic Research Laboratory, Lawrence, Mass.

Beacher, L. Lester, Sc.D., Litt.D., Biophysics. Lecturer on Contact Lenses, Optometric Foundation, East Orange, N. J.

Belford, Julius, B.S., Pharmacology. Graduate Student, Yale Medical School, New Haven, Connecticut.

Benton, Joseph G., Ph.D., M.D., Medicine. Resident Assistant, Medical Division, Goldwater Memorial Hospital, New York, N. Y.

Bercovitz, Z. T., M.D., Ph.D., Gastroenterology, Tropical Medicine. Attending in Medicine, Gastroenterology, St. Clare's Hospital, New York, N. Y.

Bernhard, Adolph, M.A., Biological Chemistry, Clinical Biochemistry. Pathological Chemist Lenox Hill Hospital, New York, N. Y.

Bernstine, Melvin L., M.D., Anaesthesia, Pharmacology. Resident Anaesthetist, Hartford Hospital, Hartford, Conn.

Braum, Werner, Ph.D., Bacterial Variation. Bacteriologist, Camp Detrick, Frederick, Maryland.

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Bush, Norman H., B.A., Cancer Research. Assisant to Doctor Anna Goldfeder, Director of Cancer Research, New York Department of Hospitals, New York, N. Y.

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Chu, C. H. U., Ph.D., Histology, Pathology of Tumors. Research Fellow, National Cancer Institute, Bethesda, Maryland.

Ciliberti, Benjamin J., M.D., Anaesthesiology. Acting Director of Anaesthesia, Halloran V. A. Hospital, Staten Island, N. Y.

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Craig, Colden L., B.A., Business Administration. Secretary-Treasurer, American Academy of Embalming and Mortuary Research, Inc., New York, N. Y.

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Feodoroff, Nicholas V., B.S., Engineering. Associate Professor, School of Engineering, Manhattan College, New York, N. Y.

Finch, Glen, Ph.D., Military Psychology. Scientific Aide, U.S.A.F., Human Resources Program, Washington, D. C.

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Fishman, William H., Ph.D., Biochemistry. Research Professor of Biochemistry, Cancer Research and Cancer Control Unit, Boston, Mass.

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Fitzpatrick, William H., Ph.D., Nutritional Biochemistry. Panel Director, Committee on Medical Sciences, Research and Development Board, Washington, D. C.

Flippin, Harrison F., M.D., Infectious Diseases. Ward Physician, University of Pennsylvania Hospital, Philadelphia, Penna.

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Misiak, Henryk, Ph.D., Psychology. Instructor of Psychology, College and Graduate School, Fordham University, New York, N. Y.

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Rosenkranz, Gabriel, M.D., Biology, Anthropology, Psychology, Physics. Orthopedic Surgeon and Research, Veterans Administration, New York, N. Y.

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Smith, Christianna, Ph.D., Histology. Professor of Zoology, Mount Holyoke College, South Hadley, Mass.

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Zimmerman, Sidney P., M.D., Internal Medicine, Cardiac and Liver Physiology. Resident in Medicine, Mt. Sinai Hospital, New York, N. Y.

Zirkle, Raymond E., Ph.D., Biological Effects of Radiations. Professor of Radiobiology, University of Chicago, Chicago, Ill.

Zuckerbrod, Morris, M.D., Internal Medicine. Clinical Assistant in Medicine, New York University, New York, N. Y.

STUDENT MEMBERSHIP

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Orsi, Ernest V., M.S., Cytology. Student, Biological Laboratory, Fordham University, New York, N. Y.

Ramm, Gordon M., B.A., Embryology, Histology. Graduate Assistant, Department of Biology, University of Buffalo, Buffalo, N. Y.

Ratzersdorfer, Carla, B. S., Endocrinology. Graduate Student, New York University, New York, N. Y.

Zollo, Dominick A., Electronics. Student of Technology, City College of New York, New York, N. Y.

ADDITIONS TO LIFE MEMBERSHIP CLASS BY TRANSFER

Anagnostis, Irene P.
Arthur, John M.
Beard, Stanley D.
Bennett, Harry
Bieber, Samuel
Bittson, A. John
Booth, Verne H.
Brokaw, Albert D.
Carey, Benjamin W.
Charipper, Harry A.
Cheney, R. H.
Cumming, Neville W.
D'Angelo, Savino Albert
Deans, Walter
Dingwall, Andrew
Ehret, William F.
Garcia, Eusebio Y.
Gee, A. Haldane
Gewanter, Aaron Philip
Gordon, Albert S.
Gresser, Edward Bellamy
Harnly, Morris H.
Hope, Fred J.
Hutner, Seymour H.
James, Thomas H.
Jones, Murray Leroy
Kempf, Edward J.
Kershner, David
Kopac, M. J.
Little, Paul A.
Long, Margaret E.
Marsland, Douglas A.
Miller, Lloyd C.
Mossman, Dorothea R.
Nigrelli, Ross F.
Northey, Elmore H.
Park, S. E.
Payne, Nellie M.
Petermann, Mary Locke
Pignatelli, Myrtle L.
Randel, Barbara
Reese, Algernon Beverly
Roblin, Richard O., Jr.
Roepke, Raymond R.
Root, Walter S.
Rothschild, James B.
Ryan, Francis J.
Schwarz, Herbert F.
Schweitzer, Jerome M.
Schweizer, Malvina
Silber, Robert H.
Suter, C. M.
Thacher, Henry C., Jr.
Tislow, Richard
Tobin, Elise
Tukey, John W.
Valentine, Wilbur G.
Weld, Julia T.
Wellnitz, Anna M.
Worley, Leonard George
Yonkman, Fredrick F.
Zahnd, Hugo

Editor's Newsnotes

President Charles Pratt announced on January 31, that the Board of Trustees of Pratt Institute has appointed Dr. Florence S. Tabor Dean of the School of Home Economics effective as of today.

Dr. Tabor, who has been Professor of Chemistry in the School of Home Economics since 1943, has served as Acting Dean for the past five months, since the resignation of former Dean Joan M. Rock.

Miss Tabor, a native of Dover Plains, Dutchess County, N. Y., is an alumna of Skidmore College. She received her Master of Science degree from New York University, and her Ph.D. in Biological Chemistry from Pennsylvania State College. After serving as chemistry instructor at Wilson College and at Vassar, she accepted a similar position at Pratt Institute in 1935.

She is a member of Sigma Xi and Iota Sigma Pi honoraries; American Chemical Society; American Association for the Advancement of Science; and the New York Academy of Sciences.